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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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CONTENTS OF VOLUME XXXI.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part. I., 1918

Art. I.—*Australasian Characeae.*

A Synopsis by

PROFESSOR NORDSTEDT, Ph.D., Lund.

(Communicated by A. D. Hardy, F.L.S.).

[Read 14th March, 1918].

More than a quarter century has elapsed since Professor Nördstedt published—at Stockholm, in 1888—"Fresh Water Algae Collected by Dr. S. Berggren in New Zealand and Australia in 1874-5"; and, at Lund, in 1891, his "Australasian Characeae, Part I." The latter comprised 10 plates, each with a specific diagnosis, of cosmopolitan application, and a description applicable to the Australasian specimens only. In a short introduction the Author stated :—

"Baron Ferd. von Mueller, who is the Author of several illustrated works on the Australian Flora, has invited me to issue a similar work dealing with the Characeae. It is with his help that I begin this undertaking, the continuation of which must largely depend upon such circumstances as the receipt of adequate material and the necessary time being available. I hope it may be the means of inducing other botanists in Australia to study these plants, and thus arrive at better results than is now possible."

The following species were figured and described :—

Nitella partita, Nordst. - -	Queensland.
„ *subtilissima*, Al. Br. -	West Australia.
„ *leptosoma*, Nordst. - -	New Zealand.
„ *tumida*, Nordst. - -	South Australia.
„ *tricellularis*, Nordst. -	New Zealand.
„ *congesta*, (R. Br.) Al. Br. -	Tasmania; North and South Coasts, Australia.
Chara Braunii, Gmel. - -	Victoria, South Australia, Queensland and N.S.W.
„ *leptopitys*, A. Br. - -	Victoria and Tasmania.
„ *l.* sub-sp. *subebracteata*, Nordst. - - - -	W.A., Victoria and N.Z.
„ *scoparia*, (Bauer), Al. Br. *C. Muelleri*, Al. Br. -	Victoria, N.S.W.

The following synopsis was prepared for private use, but as it may be of use to Australian students, Professor Nördstedt has consented to its publication :—

Synopsis of the Australasian Charcaeae.

1. NITELLA.

A. Monarthrodactylae, ultimate segments of the leaves one-celled.
- a. Simply branched.
  - ! Dioecious, nucleus with 11 striae - - *polygyra*, A. Br.
- b. Repeatedly branched.
  - ! Monoecious, segments of leaves large, nucleus 215μ long - - - - - - *Stuartii*, A. Br.

B. Diarthrodactylae, ultimate segments of the leaves 2 (rarely 3-) celled, ultimate cell mucroniform or bi-tripartite.
- a. Homeophyllae, leaves similar.
  - aa. Dioecious.
    - c1. Ultimate cells bi-tripartite - - - *partita*, Nordst.
    - c2. Ultimate cells undivided, mucroniform.
      - d1. Nucleus 180-200μ long, covered with scattered very small spines - - *Sonderi*, A. Br.
      - d2. Nucleus 230-300μ long.
        - e1. Fertile spicate heads 1½-2-2½ mm. in diameter.
          - f1. Sterile leaves branched with very short tips - - - - - *gloeostachys*, A. Br.
          - f2. Sterile leaves not branched with very short tips, nucleus punctated with minute granules - - *subtilissima*, A. Br.
        - e2. Fertile whorls not in small spicate heads.
          - g1. Nucleus covered with small dentate scales - - - - - *penicillata*, A. Br. (=*Gunnii*, A. Br.)
          - g2. Nucleus minutely granular - *Robertsoni*, A. Br.
      - d3. Nucleus 430-470μ long, with small granules, more closely together than on N. subtillissima - - - - *remota*, A. Br.
  - bb. Monoecious.
    - h1. Leaves simply branched or twice-trice-divided, the ultimate divisions not much abbreviated.
    - i1. Leaves simply branched.
    - k1. Heads not enveloped in mucus (cf. polyarthrod.) - - - *tricellularis*, Nordst.
    - k2. Heads enveloped in mucus - *microphylla*, A. Br.
    - i2. Leaves repeatedly branched.
    - l1. Leaves (commonly) only twice divided (seldom more)
    - m1. Antheridium 350μ - - - *conformis*, Nordst.

m2. Antheridium 165-200μ, nucleus 300-350μ long, with 8 striae - *leptosoma*, Nordst.

m3. Antheridium 150-166μ, nucleus 230-250 (-300)μ long, 6 striae, minute - - - - - - *batrachosperma*, (Rchb.) A. Br.

m4. Antheridium 200-230μ, nucleus 300-320μ long, 6-7 striae, large - *pseudoflabellata* f. *mucosa* (partly).

l2. Leaves commonly trice divided, ultimate segments (3-) 4-6 (-7), primary segment longer than half the divided leaf, nucleus 300-360μ *pseudoflabellata*, A. Br.

———fruit enveloped in mucus f. *mucosa*, Nordst.

h2. Sect. Polyglochin or Brachydactylae. Upper leaves, in part often four times divided, the ultimate divisions (almost always sterile) forming a 2-4-cuspidate crown.

n1. Coronula of the sporangium short.

o1. Oogonia solitary - - - - *oligospira*, A. Br.

o2. Oogonia aggregated - - - *microcarpa*, A. Br.

n2. Coronula of the sporangium elongated - - - - - - - *polyglochin*, A. Br.

b. Heterophyllae. Leaves dissimilar (some smaller ones in the same verticil as the larger).

p1. Dioecious.

q1. The ultimate segments inflated - *tumida*, Nordst.

q2. The ultimate segments not inflated

r1. The small adventitious leaves fewer (1-20), larger leaves 1-3 times divided.

s1. Smaller leaves 1-6 (-12), terminal segments of leaves commonly 3-5, stem 250-720μ in diam. - - *conglobata*, A. Br.

s2. Smaller leaves about 14, ultimate segments of leaves commonly 5-7, stem about 1 mm. in diam., spec. doubtful - - - - - *heterophylla*, A. Br.

r2. The small adventitious leaves about 40; the larger partly 4 times divided - - - - *congesta*, A. Br.

p2. Monoecious - - - - - *hyalina* (DC.), Kütz.

C. Polyarthrodactylae. Ultimate segments of the leaves 3-6-celled, often not mucroniform.

s1. Dioecious.

t1. Fertile veticills not contracted into heads, sterile leaves of lower verticills simple - - - - *diffusa*, A. Br.

t2. Fertile verticills contracted into heads, more or less dense or interrupted.
u1. Fertile and sterile leaves 3-4-divided, terminal cell of the last segment nearly as thick as the penultimate cell - - - - *myriotricha*, A. Br.
u2. Sterile leaves often simple, fertile 1-2 divided.
v1. Nucleus 300-380μ long - - *cristata*, A. Br.
v2. Nucleus 200-270μ long, fertile heads in mucus.
x1. Fertile verticills loosely condensed, terminal segments of the leaves acute, gradually attenuate - - *tasmanica* (F. Müll) A. Br.
x2. Fertile verticills densely contracted, terminal segments obtuse *gelatinosa*, A. Br.
v3. Nucleus 160-180μ long, with 5 striae - - - - - - *polycephala*, A. Br.
s2. Monoecious.
y1. Fertile verticills not contracted into elongated, gelatinous spikes *Hookeri*, A. Br.
y2. Fertile verticills contracted into elongated, gelatinous spikes (interrupted at the base.
z1. Slender; terminal segments of the fertile leaves 2-3-celled - - *leptostachys*, A. Br.
z2. Stouter; terminal segments of fertile leaves bicellular - - *interrupta*, A. Br.
z3. Fertile verticills contracted into small, not gelatinous heads - - *tricellularis*, Nordst.

2. TOLYPELLA.

a. Monoecious, ultimate cells obtuse - - - *glomerata*, (Desv.) Leonh.
b. Dioecious, spec. nova (?), according to Groves.

3. LYCHNOTHAMNUS.

Monoecius, oogonia and antheridia on different nodes of the same plant; radical, unicellular, globose bulblets - - - - *macropogon*, A. Br.

4. CHARA.

A. Haplostephanae. Crown of stipulae consisting of a single (simple) series of cells.
a. Ecorticatae. Stem and leaves naked.
c1. Dioecious. Bracts minute or wanting - *australis*, R. Brown.
Terminal segment of leaves short, obtuse (not acute or apiculate) subspec. - *plebeja*, A. Br.
c2. Monoecious.

d1. Antherida and oogonia conjoined. Bracts on all the nodes of the leaves — *Braunii*, Gmel. (=*coronata*).

d2. Antheridia and oogonia separated, oogonia, but not antherida, in the fundus of the verticil - *succincta*, A. Br., f. *novicaledonica*, Nordst. ined.

b. Corticatae. Stem variously corticated.

e1. Haplostichae. Series of cortex cells equal to the number of leaves.

f1. Dioecious - - - - - *submollusca*, Nordst.

f2. Monoecious - - - - *myriophylla*, F. Müll., A. Br.

e2. Diplostichae. Series of cortex cells double the number of leaves.

f1. Dioecious.

g1. Both antheridia and oogonia in the fundus of the verticills - *leptopitys*, A. Br., and subsp. *subebracteata*, Nordst.

g2. Neither antheridia nor oogonia in the fundus of the verticill (small, slender, stipules pressed against the verticill).

h1. Unistipulatae. Stem with small papillae - - - - - *mollusca*, A. Br.

h2. Bistipulata. Stem more or less spinescent - - - - *dichopitys*, A. Br.

f2. Monoecious.

i1. Gymnophyllae. Leaves usually naked.

k1. Stipules large.

l1. Antheridia and oogonia on the same node. Nucleus black with many different forms, as: aequistriata (subf. polyphylla), f. tylacantha, v. duriuscula, acanthopitys and trachypitys. — *gymnopithys*, A. Br.

l2. Antheridia and oogonia on different nodes of the same leaf (verticil with 14-16 leaves) *Griffithii*, A. Br.

k2. Stipules small (nucleus black or brown) - - - - - *Drummondii*, A. Br.

i2. Gymnopodes. Leaves usually corticated, except the first, lowest node - - - - *Hydropitys*, A. Br. (not seen in Australia).

e3. Triplostichae. Series of cortex cells triple the number of leaves - - *Muelleri*, A. Br.

B. Diplostephanae. Circle of stipules consisting of a double (rarely triple) series of cells.

l1. Diplostichae. Series of cortex cells double the number of leaves

m1. Tylacantae. Primary cells (with the spines) of the cortex prominent (monoica) - - - - *contraria* and v. *Behriana*, A. Br..

m2. Aulacantae. Secondary cells of the cortex prominent - - *foetida*, A. Br.

l2. Triplostichae. Stem triply corticated.

n1. Phloeopodes. Basal segment of the leaves corticated

Monoecious.

o1. Nucleus black - - - - *fragilis*, Desv.

n2. Nucleus yellowish - - - *leptosperma*, A. Br. (dubious as Australian).

n2. Gymnopodes. The first segment of the leaves naked - - *gymnopus*, A. Br., v. *ceylonica* (Klein), A. Br., which name is older than gymnopus.

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART 1, 1918].

ART. II.—*Teratological Note.*

PENTAMERY IN A FLOWER OF NARCISSUS.

BY A. D. HARDY, F.L.S.

[Read March 14th, 1918].

In the specimen before us—"*Narcissus tazetta* ("Soleil d'or," a polyanthus Narcissus of the "parvi-coronati" group)—we have an inflorescence in which one of the flowers simulates a dicotyledonous bloom. It is the only one of the kind seen by me, although many thousands of blooms were examined during the past spring season.

The term "doubling," as used by many gardeners, denotes multiplicity of any floral part, usually the petals, but by arithmetical doubling we should have, in place of a flower with floral formula (K3; C3; A3 + 3; G3) one with formula (K6; C6; A6 + 6; G6), a phenomenon explained as due to a splitting of the primordial papillae from which the organs develop; but instead of the formula indicative of the simple type or its double, we have in the present specimen (K5; C5; A5 + 5; G5).

The size of the perianth lobes, or corona, relative position of the whorls, length of ovary and perianth tube, and length of the five stigmatic lobes are all normal. It is a case of regular polyphylly affecting—not the number of whorls, but the members only, so that we may avoid the use of the comprehensive term, "positive dédoublement" (of Celakovsky), which Worsdell[1] perpetuates. But the numerical increase of whorl members has resulted in a conspicuously larger flower of which the coronal diameter is disproportionate to the diameter of the perianth; these compared with the normal being respectively as [15 mm. : 7 mm.] and [35 mm. : 25 mm.] The corona shows no sign of division or dismemberment into staminoid or petaloid units. The increased diameter of the flower is due not to increased length of perianth segments, but to these parts having been thrust farther out by the expansion of the perianth tube ("zona perigyna") to accommodate the increased number of essential organ of fertilisation. These latter are so crowded in the orifice of the tube as to choke it, and when the flower was fresh

1. W. C. Worsdell, F.L.S. "Principles of Teratology, Roy. Soc., 1916."

and its parts undisturbed, the entrance pores (which may be found as inter-antheral spaces in a normal bloom) were -almost obliterated. It would have been difficult, if not impossible, for the tongue of a lepidopterous agent to be thrust through, yet in the attempt sufficient pollen could have been conveyed thence by the baffled insect to effect cross pollination. After almost exhaustive inquiry, I have found only one record of an occurrence somewhat similar, though both irregular and rhythmic polyphylly have been recorded for Narcissus and other allied plants; and I have seen, but failed to preserve, flowers of *Narcissus* answering to the following formulae :—(K3 ; C4 ; A3 + 3 ; G3), (K3 ; C3 ; A3 + O ; G3), and (K or C3 ; A3 + 3 ; G3), cases in which the modication appears to have been due to suppression of a whorl or a member, or (as in the first case) an increase, on no clearly discernible plan. Worsdell,[1] however, records an approximate case of polyphylly of *Crocus* :—K4 ; C4 ; A4 ; G4 and K5 ; C5 ; A5 ; G5, and of *Tulipa*, K4 ; C4 ; A4 + 4 ; G5. Also, he quotes Buchanan as having described the like, observed in *Lilium croceum*. It may be noted here that Worsdell[2] associates rhythmic alternation in increase of members of whorls, such as :—

K5 ; C4 ; A5 + 4 ; G5 (*Tulipa*)
K3 ; C4 ; A3 ; G4 (*Crocus*)
K4 ; C3 ; A4 + 3 ; G4 (*Galanthus*)

with heterotaxis of a spiral nature. Church,[3] on the other hand, finds in the early development stage of *Narcissus* a normal asymmetry and spiral formation which, however, disappear during the maturation of the flower. In the present case there is no visible spiral taxis or torsion.

1. Loc. cit.
2. Loc. cit.
3. A. H. Church, M.A., D.Sc. "Types of Floral Mechanism, Pt. I., 1908."

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part I., 1918].

Art. III.—*Abnormal Renal Portal Circulation of a Frog.*

By ALICE OSBORNE, B.Sc.

(With Plate I. and one Text Figure).

[Read April 11th, 1918].

I must thank Dr. Buchanan, of the University of Melbourne, for bringing this frog (Hyla aurea), showing an abnormal Renalportal circulation, under my notice.

It is not an uncommon occurrence to find abnormalities in the anterior veins, as well as in other parts of Hyla aurea; but variations in the portal systems are much less frequent.

The abnormality under comment was seen in the Renal portal system of the right side only—that of the left side being quite normal and consisting mainly of a double Renal portal vein.

The Renal portal vein normally arises from the union of the sciatic and the iliac veins. On the right side of this specimen the iliac vein was slightly longer, and the vein formed by the union of the sciatic and iliac veins, which for convenience sake I shall refer to as Renal portal, A, was a large vessel entering the lateral edges of the kidney more anteriorly than did the Renal portal of the left side.

So far as the origin of the vessel, A, was concerned, it corresponded exactly to the normal Renal portal vein, with, however, one difference, viz., the dorso-lumbar vein instead of opening separately and anterior to the Renal portal vein, in this case opened directly and somewhat backwardly into the vessel, A.

In addition, there was another longitudinal vessel, Renal portal vein, B, opening into the kidney in a position corresponding to the entrance of the left Renal portal vein into the left kidney.

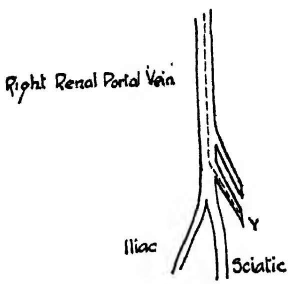
This Renal portal vein, B, arose in the dorsal wall of the pelvic region, and had a slight connection along its length with a vessel which arose from the dorsal pelvic region, and emptied its blood into the inner side of the left Renal portal vein.

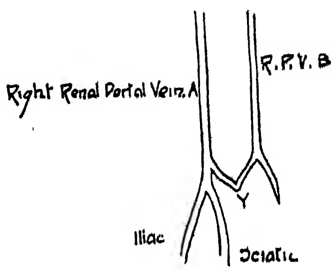
The latter vessel occurs quite frequently, but appeared somewhat enlarged in this case.

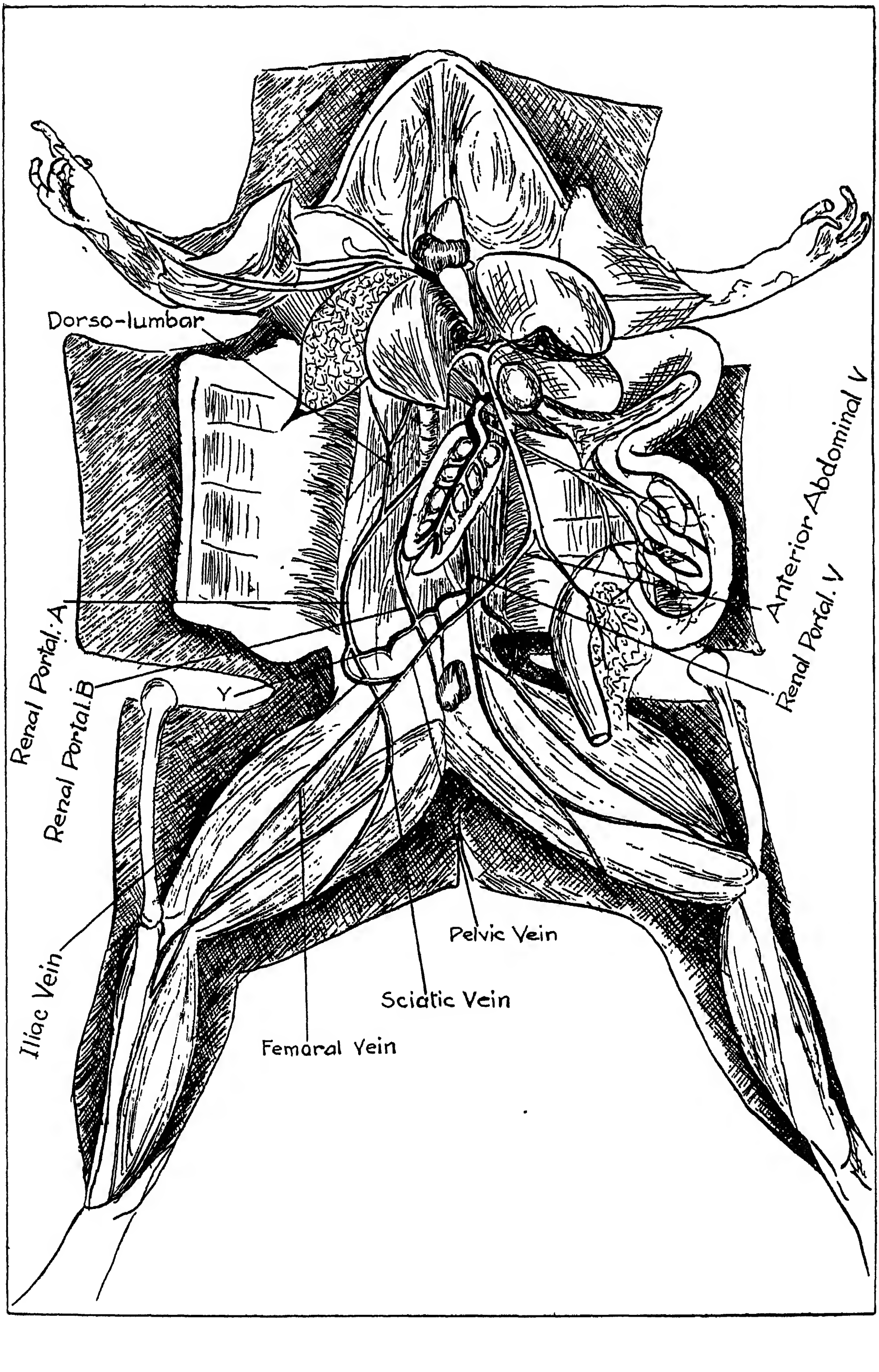
Between the right Renal portal veins A and B was a somewhat curious connection Y, the middle of which received branches from the deeper layers of muscle around the pelvic region.

As a result of this alteration in the course of the blood supply one might expect to find the kidney of the right abnormal side enlarged; but this was not so, both kidneys being of normal size.

It is difficult to find any reason for this abnormality, but it seems possible that during early development the Renal portal vein split into two along its length, and likewise part of vessel Y, the two vessels separated widely, and the two halves of Y separated along the divided part of their lengths, but kept a connecting link showing where the splitting ceased.







Dorso-lumbar
Anterior Abdominal V
Renal Portal. V
Renal Portal. A
Renal Portal. B
Y
Iliac Vein
Pelvic Vein
Sciatic Vein
Femoral Vein

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part I., 1918].

Art. IV.—*Relationship of Insects to Parasitic Diseases in Stock.*

By GERALD F. HILL, F.E.S.

(Walter and Eliza Hall Fellow).

(With Plates II.-VIII.).

[Read May 9th, 1918].

Part I.—The Life History of Habronema muscae, H. microstoma, and H. megastoma.

Introduction.

Although the life history of *Habronema muscae* has been known for some years as a result of the investigations made in U.S.A. by Dr. B. H. Ransom, there are no records of any such investigations in Australia, where variations tend to occur in the case of certain parasites owing chiefly to climatic and associated conditions.

Of the life histories of Habronema microstoma and H. megastoma nothing appears to be definitely known either in Australia or elsewhere.

In the adult stages these species of Habronema are well-known as more or less common stomach parasites of the horse, their occurrence under ordinary conditions being generally believed to be of little detriment to the health of the host. During recent years, however, more attention has been directed to these parasites in Australia as a result of the discovery here of larval Habronema, or an allied form, as the supposed causative agents of pathological conditions of the horse known as "Habronemic granulomata" and "Habronemic conjunctivitis." Further, splenic and stomach abscesses of the horse, due to H. megastoma, appear to have become of more frequent occurrence during the past few years, and there is reason to believe that under certain conditions the mortality caused in stock is considerable. These considerations then emphasised the desirability of testing under local conditions the life history of Habronema muscae, and of acquiring a knowledge of the life histories of other allied species.

Technique.

Among the first essentials for this work were means of obtaining (1) a pure culture of the parasite under investigation, and (2) absolutely "clean" flies, i.e., flies quite uncontaminated by any sort of helminth infection.

The former of these proved quite easy after some practice. All nematode eggs and embryos used in these experiments were obtained directly from gravid females, each of which was specifically determined whilst alive. After a thorough washing in saline solution these adults were placed in a watch-glass with a small quantity of sterilized normal saline, and cut into fragments between two needles, the contents of the glass were then washed off with the same fluid into a 4-oz. wide-mouthed bottle nearly full of fresh horse faeces, previously sterlized in the ordinary way in an autoclave for twenty minutes under a steam pressure of twelve pounds to the inch.

The second essential was finally secured by the adoption of methods which are here given somewhat fully in the hope that they may be of use to other workers, as a considerable amount of time had to be spent in perfecting the technique of breeding the flies and handling and preparing the worm larvae, as also in preliminary observations and experiments before the more systematic work of the investigations could be commenced.

Musca domestica.

Museum jars 8 in. high, and having an opening of 4 in. x 2 in., were obtained for the reception of the nidus. A sleeve to fit closely over these jars was then made by taking a piece of wire-gauze (12 meshes to the inch), about 8 in. wide by 14 in. long, and wrapping it tightly around the jar, while in this position the overlapping edges of the gauze were secured with solder and strengthened by a narrow strip of tin soldered along the whole length of the overlap, the top and bottom edges of the sleeve being similarly strengthened. In this way a sufficiently rigid and closely fitting, but removable, cage was made, which could be slipped over one edge of the jar, its outer open end being closed by a piece of paper folded over the edges and secured with a rubber band.

A strip of tin 1½ in. wide and of sufficient length was then laid across the middle of the glass jar at the open end, bent sharply down each side for a distance of 1¼ in., then turned sharply upwards and snipped off about ¾ in. from the bend. This apparatus served as a clip to hold the gauze cage in position, and also as a receptacle for food.

In starting an experiment the jar is two-thirds filled with previously sterilized and cooled horse faeces, and the clip fixed in position, whilst the flies are caught in the vicinity of the stables in an ordinary butterfly net, with the end of the bag secured by a short piece of twine instead of the usual permanent stitching. As soon as a sufficient number of flies of the required species are caught, they are forced to the extreme end of the net by a few rapid sweeps, and imprisoned there by a few twists of the bag behind them, the twine is then untied, and the end of the net inserted well into the open end and towards one side of the otherwise closed gauze cage, which is then slipped over the mouth of the jar and forced down until its lower edge rests firmly in the metal clip. In a few minutes the flies find their way out of the open end of the net and congregate at the top of the cage. The cage is then tipped up sufficiently to permit of the withdrawal of the net and again forced down until it rests in the clip, the free ends of which are pressed firmly against the sides of the jar to hold the cage in position.

The best results were obtained when the flies were fed soon after being placed in captivity. For this purpose blood, sugar and water, cow's milk, and a preparation of dried separated milk, with the addition of water, were tried. The latter being readily obtainable at all times, and easily prepared, was found to be the most satisfactory. The liquid food was conveyed to the strip of tin across the mouth of the jar by means of a pipette passed through the meshes, the cage was then placed in the sunlight, or, in dull weather, near an electric radiator.

As a rule, sufficient eggs were deposited during the first day of confinement; if not, the flies were again fed and left for another day. When sufficient eggs were secured, the flies were liberated or removed in the gauze cage to another similar breeding jar, and the first jar covered with paper retained in position by means of a rubber band.

No special precautions were taken to maintain the eggs and larvae at a uniform temperature except that, as a rule, during the winter months they were kept in an improvised incubator, or near the electric radiator, at a temperature ranging from 20°C. to 28°C. During the summer months artificial heating was not resorted to.

On alternate days the larvae were supplied with freshly sterilized faeces, sometimes added to the top of the earlier supply, but more often placed in a clean jar. In the latter case the larvae were separated from the old faeces by merely turning the first jar into

another jar containing a few inches of fresh matter. In a few minutes the larvae migrated to the newer material, leaving the old to be removed and replaced by a more abundant supply of fresh food.

In some cases the pupae were removed from the faecal matter, washed in sterile physiological salt solution and transferred to moistened sterilized sand, but as this method did not appear to possess any advantages over the simpler procedure of allowing them to remain in the jar in which they had developed, it was discontinued.

On the appearance of the first flies the metal clip and gauze cage were fixed in position over the jar, and within a few hours sufficient flies were secured to breed from. The cage containing the newly emerged flies was then rapidly fitted to a clean empty jar, and food was introduced into it in the manner described.

Food was given once or twice daily for about eight days, during which period the flies were transferred on alternate days to clean cages and jars, and were kept as far as possible in a warm, sunny situation by day and near a radiator at night. Under these conditions they mated in four to six days after their emergence from the pupae and oviposited about four days later. On the eighth day the cage and its contents were transferred to a clean jar, containing freshly sterilized faeces, to which the flies had access until a sufficient number of eggs were deposited. The flies were then transferred to another similarly prepared jar for the production of more eggs, whilst the jar containing the first batches of eggs was covered with paper and transferred to a warm situation. The eggs hatched 12-24 hours later, producing larvae which, like their parents, had been reared exclusively on sterilized matter. It is obvious that any chance of helminth infection in these "clean" larvae is almost, if not quite absent, as shown also by the negative results of the examination of flies bred on such sterile faeces, and by the invariable absence even of moulds and such like from the jars. Such larvae were used in all the experiments in which this species (Musca domestica) were concerned, excepting where the contrary is stated. It may be mentioned here that the writer has succeeded in rearing four generations of flies in the laboratory under these methods.

Stomoxys calcitrans.

The methods employed for obtaining the larvae of Stomoxys calcitrans for experimental purposes differed from those outlined above only in the following details :—The adult caught flies did not

require to be fed during their captivity, and larvae of the first generation only were reared, and used in all the experiments with this species, owing to pressure of time when these flies and the Helminth material were obtainable.

A.—Habronema muscae, Carter.

1.—Historical.

A full account of the life-history of Habronema muscae, Carter, known since 1861 as a parasite of the House-fly (Musca domestica), was published by Dr. B. H. Ransom in 1913. As a result of his investigations it was shown that the life-history of this nematode is one requiring for its completion a simple alternation between two hosts, a vertebrate harbouring the adult parasite and an invertebrate harbouring the larval stage.

From horse faeces collected in the streets of Colorado Springs, U.S.A., on August 9th, 1911, Ransom bred flies (M. domestica) from which in the larval, pupal, and adult stages, he obtained a series of nematode larvae in successive stages of development commencing with a stage measuring about 0.4 mm. in length, from a fly larva, and reaching a maximum length of 3.2 mm. in an adult fly. On September 11th, 1911, he found amongst numerous filarioid worms collected from the stomach of a horse, larval worms in the same stage of development as those from flies. The adult worms from the horse's stomach were all of one species, and the younger stages formed a series between the adults on one hand and the larval Habronema muscae from flies on the other, thus establishing the fact that Habronema muscae of the fly, Musca domestica, is the larval stage of a parasite, the adult stage of which occurs in the stomach of the horse.

This parasite was shown to be similar to, but distinctly different from, a species found in the stomach of the horse, and known since 1886 as Spiroptera microstoma (Schneider), now correctly designated Habronema microstoma (Schneider).

In a further account of the development of the larvae of Habronema muscae within the body of the fly, Ransom gives details and drawings of six definite stages through which the parasites pass before reaching the stomach of the definitive host, to which stages reference will be made later on.

Seurat (1916, p. 321) considers that Ransom is quite wrong in describing these different steps in the development of the larval Habronema muscae within the fly (pupa and adults), as true stages,

this term being more correctly used to designate one of the five stages of increasing complexity of development characteristic of nematodes, each of these being separated from its predecessor by a distinct moult.

The same author (1912, p. 78) records the occurrence of both Habronema muscae and Habronema microstoma in horses and mules in Algiers.

Work upon somewhat similar lines to my own is being carried out by Mr. L. B. Bull, B.V.Sc., at the Government Pathological Laboratory, in Adelaide. A preliminary manuscript account of this Mr. Bull has very courteously allowed me to read while in the press, and also he has discussed certain points with me.

2.—The Adult.

Until very recently the presence of Habronema muscae in the stomach of horses in Victoria has not been recognised, although H. megastoma and H. microstoma have been well known. There is little doubt, however, that this has been due to a lack of distinction between H. muscae and H. microstoma, for since this investigation has been in progress, H. muscae has been found to be much more common than H. microstoma, and some specimens hitherto regarded as H. microstoma have turned out to be H. muscae on closer examination.

In the adult stage the parasite (H. muscae) occurs very frequently in the stomachs of horses in Victoria. A census of the parasites found in 39 horses' stomachs which were examined during the progress of this work shows that 33 of these harboured H. muscae. Further reference will be made to this in the general discussion later on.

In view of the excellent full description given by Ransom of the structure of this parasite, it is quite unnecessary here to attempt to add anything to it.

So far as is known, this species acts similarly to H. microstoma in its host.

3.—Record of Experiments, and Special Observations.

A. To determine the relationship of H. muscae to Musca domestica as an intermediate host.

Experiment No. 1.

Embryos from numerous H. muscae were liberated in sterile faeces at noon on October 30th, and incubated at a temperature

of 22°C. until noon on November 7th (eight days), when Musca domestica larvae (two days old) were liberated in the vessel. On November 20th and 21st fifteen flies were examined, ten of which were infected with from two to fifteen larval Habronema each. About half the total number of parasites were enclosed in cysts in the abdomen, the remainder were free in the abdomen, thorax, or head.

Experiment No. 2.

This experiment was similar to No. 1, excepting that the embryos were incubated for a period of 42 hours only (from 4 p.m. on November 20th to 10 a.m. on November 23rd). The fly larvae were of the same age and character as those used in Experiment No. 1 (i.e., two days old). Between November 26th and December 8th, 16 larvae, 12 pupae and 15 flies were examined, of which 1 larva, 1 pupa and 4 flies contained Habronema larvae.

Experiment No. 3.

Embryos from 20 H. muscae were liberated in faeces with a number of Musca domestica larvae (three days old), at 3.30 p.m. on November 26th. Between December 4th and 10th, 29 pupae and 12 flies were examined, of which 9 pupae and 5 flies were positive for Habronemic larvae. The infected pupae contained four or five parasites each, and the infected flies two to twelve parasites each. Twelve of the total number of parasites found in the flies were enclosed in cysts.

Experiment No. 4.

Embryos from numerous adult H. muscae were liberated in faeces at 4 p.m. on November 28th, with fly larvae then four days old. Between December 5th and 7th 1 pupa and 38 flies were examined, of which the pupa and 3 flies were positive. The pupa contained five parasites.

B. To determine the possibility of Stomoxys calcitrans acting as an alternative intermediary host.

In both these experiments Musca domestica was used as a control as to the viability of the Helminth embryos.

Experiment No. 5.

Embryos from ten worms were incubated in faeces from December 21st to December 27th, when larvae of Musca domestica and Stomoxys calcitrans, which hatched about December 18th, were

liberated in the vessel containing them. The Stomoxys larvae produced only one fly (January 7th), the result of examination of which was negative. Between January 7th and 8th, 34 Musca domestica flies were examined, 21 of which were positive and 13 negative for Habronema. The abdomen only of each of these Musca domestica flies were examined, the number of parasites found in each varying from four to sixteen. Both species of fly larvae used in the experiment were the progeny of eggs laid in the laboratory on sterilised faeces by naturally bred flies.

Experiment No. 6.

After a period of incubation in faeces, from 11 a.m. on January 11th to 11 a.m. on January 16th, larvae of Musca domestica and Stomoxys calcitrans were liberated in the embryo-infected faeces. These fly larvae hatched on January 7th, and were, therefore, nine days old when exposed to infection. On January 30th and the two following days, 15 Musca domestica flies were examined, all of which were positive for Habronema, the number of parasites in each varying from three to thirteen. On January 31st, and the five days following, 49 Stomoxys flies were examined, all of which were negative.

C. To determine the frequency of larval Habronema in Musca domestica, and their abundance and location in the body of the intermediary host.

(i) Free or caught flies.—During the period May-November, 1917, a record was kept of the number of flies (M. domestica) caught in the stables, and examined for the presence of Habronema larvae. It shows that 182 adult flies were examined, 14 of which were infected with Habronema muscae (?), as follows:—Eight harboured one parasite each in the head, one harboured two parasites in the head, one three in the head, four one parasite each in the abdomen.

(ii.) Although a similar record of laboratory bred flies has not been kept, it has been noticed that in the great majority of cases the abdomen only was infected, the proportion found in the head being much smaller than in the abdomen. This was particularly noticeable in heavily-infected flies.

The occurrence of Habronema larvae in the distal portion of the proboscis (haustellum) of Musca domestica has not been observed by the writer, although their occurrence in the proximal portion

(rostrum) is not unusual (Fig. 17). The greater proportion were found in the posterior part of the head capsule.

Ransom (1913, p. 13), states that the largest number of larval worms he found in an individual fly was eight, though, as he remarks, Carter (1861) noted as many as twenty in one fly.

The largest number of larvae, almost certainly H. muscae, found by the writer in a naturally infected fly (i.e., a fly caught in the stable) was three, but flies reared in the laboratory from larvae fed upon artificially infected faeces have produced a much greater number of parasites. Under these conditions 25 to 30 larval H. muscae in a single fly is not an unusual occurrence, while from one fly 72 of these parasites were obtained.

D. The viability of embryonic Habronema muscae in faeces.

It has been shown (Experiment No. 1, p. 8), that embryonic Habronema muscae removed from the uteri of gravid worms and incubated in sterilized faeces at a temperature of 22°C., may retain their viability and are capable of infecting fly larvae for a period of eight days.

In view of the results of similar experiments with the embryos of H. microstoma (see later Experiment No. 10, p. 26), it seems possible that this period may be considerably lengthened. Under the most favourable natural conditions it is conceivable that embryos may retain their viability for equally long periods.

E. To determine the period of survival of larvae removed from flies.

On January 7th, ten larval H. muscae from the abdomen of a fly were placed in saline solution in an open dish. On the following day two of the larvae were motionless and apparently dead, three more died on each of the two following days, leaving two nearly motionless larvae, both of which succumbed before noon on January 12th. Thus none of the larvae survived more than five days, although under similar conditions Ransom (1913, p. 14) found the longest period of survival to be between five and eight days.

F. To determine the period of survival of larval H. muscae in dead flies.

Twelve flies which emerged on December 4th, and died on the 6th, were placed on moist filter paper in a covered Petri dish at noon on the latter date. Twenty-four hours later four were examined, two of which contained 13 living larvae, several of which were

however, motionless. At noon on the following day (December 8th) the remaining eight flies were examined, three of which harboured 12 larvae. Of these nine were dead and three succumbed a few hours later in saline solution. Thus the longest period of survival was about two days, thus confirming Ransom's observations (1913, p. 14).

G. To determine the possibility of escape of larval Habronema muscae from flies.

On many occasions living flies were placed in moistened Petri dishes with the object of determining whether, under such conditions, the parasites could escape either before or after the death of the flies. In no instance could larvae be found in the dishes, although from subsequent examinations it was proved that the flies were heavily infected.

Similar negative results were obtained in experiments in which infected flies were allowed to die and remain for periods up to two days in saline solution.

Development.

The eggs and developing embryos, as found in the gravid female, are shown in Fig. 1. The egg (Fig. 1a) measures from 0.04 mm. to 0.05 mm. in length by 0.01 mm. to 0.013 mm. in breadth. Progressive stages of development are shown in Fig. 1, b, c, d, e, and f, in all of which the embryo is enclosed in a thin elastic sheath or egg-shell. In the stages shown in Fig. 1, e and f, two or three nuclei are usually seen, the largest being about 0.033 mm. to 0.036 mm. from the anterior end, the others at distances varying from 0.015 mm. to 0.035 mm. from the posterior end. A clear space surrounding what appears to be the rudimentary pharynx is rarely, though very indistinctly, seen. What appears to be a horn-like process at the anterior end can be made out with difficulty in the stage shown in Fig. 1, f.

The dimensions of the specimens figured are as follows :—(a) 0.043 mm. long by 0.013 mm. wide, (b) 0.052 mm. long by 0.0132 mm. wide, (c) 0.053 mm. long by 0.018 mm. wide, (d) 0.069 mm. long by 0.009 mm. wide, (e) 0.075 mm. long by 0.007 mm. wide, with nucleus at 0.033 mm. from the anterior end. In d, e, and f, the measurements given are of the embryo only, exclusive of the enveloping sheath, which varies in shape and size with the movements of the embryo, and no allowance is made for the bent tail end.

As Ransom has stated (1913, p. 16) the embryos undoubtedly pass out of the body of the horse in the faeces. Fig. 2 shows an embryo

0.089 mm. long by 0.0066 mm. wide, which was found in fresh horse faeces collected in a stable yard on October 11th, 1917. While this and many other embryos found under the same conditions have not been identified, there is little doubt that they are some species of Habronema. In this embryo there was a conspicuous nucleus at about 0.036 mm. from the anterior end, and a smaller one nearer the posterior end. It was not enveloped in a sheath or shell.

Two other embryos, each enveloped in a sheath, found in the same lot of faeces, measured 0.0925 mm. and 0.09 mm. in length respectively. In each the sheath was rather closely applied to the body except at the posterior end, where it was held away by the curved tail. The outline of the head could not be clearly seen in either of the embryos, but it appeared to be as shown in Fig. 2.

Development of the embryo in faeces.

No apparent development of the embryo takes place during its passage through the intestines of the horse, the embryos found in the uterus being indistinguishable from those found in fresh horse faeces. A certain amount of development does, however, take place during the life of the embryo in faeces. Fig. 3 shows an embryo obtained from a gravid female, which, with many other embryos, was incubated in sterilized horse faeces for a period of six days at room temperature. This embryo, which measured 0.086 mm. long by 0.065 mm. wide, was enclosed in a sheath 0.109 mm. long. The pharnyx, followed by a bi-lobed clear area and a granular and nucleated mass along the middle line of the body, could be fairly distinctly seen. The large nucleus was 0.036 mm. from the anterior end. Other embryos examined measured from 0.072 mm. to 0.086 mm. long by 0.0066 mm. wide, each being enclosed in a sheath measuring from 0.0825 mm. to 0.109 mm. long.

It is not known whether the embryos enter the fly larvae forcibly or whether they are ingested passively. Ransom considers that the latter is the more plausible theory, and in this I concur.

The early stages of Habronema muscae in the intermediary host (Musca domestica).

In larvae of M. domestica.

The earliest stage in which H. muscae are known to occur in the larvae of Musca domestica is shown in Fig. 4. This embryo, which

is four and two-third days old, was found in the alimentary canal of a Musca domestica larva, then five days old. The embryo was one of many which had been taken from a gravid Habronema muscae, and incubated in sterilized faeces at a temperature of 22°C. for 42 hours, at the end of which period they and the faeces were offered to fly larvae, then 48 hours old.

The embryo measured 0.0905 mm. in length by 0.0066 mm. in breadth, and agreed closely with the specimen shown in Fig. 3, excepting that it was free and not enclosed in a sheath.

Great difficulty is experienced in finding these embryos in fly-larvae, owing to their small size and transparency, and the nature of the debris surrounding them. The occurrence of other species of nematode worms in fly larvae, which, as Ransom has pointed out, aggravates this difficulty, has been obviated by the technique employed in these experiments.

In pupae of M. domestica.

Nothing is known of the further development which takes place in the young nematode larvae until the stage shown in Fig. 5 is reached. The specimen shown in Fig. 5 measured 0.25 mm. in length by 0.05 mm. in breadth at the posterior end of the oesophagus. The shallow mouth cavity appears to be followed by the oesophagus, but this structure could not be clearly seen owing to the fact that the cuticle was separated from the body at the anterior end, showing that the larvae was in process of moulting. It will be noted that in general appearance, this larva (measuring 0.25 mm. in length) agrees closely with the stage designated Stage 1 by Ransom (1913, p. 16), which measures from 0.4 mm. to 0.45 mm. in length (see later figures).

The same fly pupa contained two other larvae, a younger one measuring 0.2 mm. in length, which was not in process of moulting, and an older one, measuring 0.65 mm. in length (see Fig. 9). The embryos which produced these larvae were obtained from a gravid H. muscae on November 26th, mixed with saline solution and a small quantity of sterilized faeces, and fed to fly larvae which hatched on November 23rd. The pupa was examined on December 3rd; the oldest parasite was therefore not more than seven days old.

The next stage in the development of the larvae is shown in Fig. 6. This larva, from a fly pupa, was found on December 4th in the same culture as those referred to in the preceding paragraph.

The shallow oral cavity is followed by a straight pharnyx, which

was surrounded by a somewhat clear space extending nearly to the body wall. Its total length was 0.3 mm. the oesophagus was 0.117 mm. from the anterior end, and the diameter at the anterior margin of the rectum was 0.054 mm.

On the same date another larva of similar appearance, measuring 0.27 mm. in length, 0.05 mm. in width near the rectum, and having an oesophagus 0.11 mm. long, was found in a pupa from the same culture.

The larva shown in Fig. 7 is in the same stage of development as that shown in Fig. 6. It measured 0.34 mm. in length, 0.04 mm. in width at about the posterior end of the oesophagus, 0.05 mm. in width near the rectum, and 0.04 mm. from the anus to the tip of the tail. There was a constriction in the intestine near the junction with the oesophagus, but in living specimens this was seen to be due to the movements of the intestine itself. That the process of moulting had commenced was shown by the presence of the old cuticular lining of the oral cavity becoming detached from the body.

Fig. 8 agrees with the stage figured and described by Ransom 1913, p. 17, under the designation Stage 1, i.e., the earliest stage of H. muscae definitely known to him to occur in Musca domestica. The parasite shown in Fig. 8 was found on December 6th in a fly pupa, resulting from a larva which hatched on November 24th, and had lived on a culture of H. muscae embryos in sterilized faeces since November 28th, the date on which the embryos were obtained from a gravid worm.

The larva (Fig. 8) measures 0.45 mm. in length by about 0.045 mm. in width at the anterior end of the intestine. The oesophagus increases in diameter from 0.01 mm. at the anterior end to about 0.02 mm. at the posterior end. A nerve ring could be seen indistinctly at about 0.07 mm. from the anterior end. The intestine was about 0.18 mm. in length, and slightly narrowed towards the posterior end.

It will be noted that the clear space surrounding the pharynx of both younger and older stages is not shown in this larva. The moulting condition of the anterior end, and the consequent effect upon microscopical appearance may possibly account for the apparent absence of this feature. These remarks may apply also to the larva shown in Fig. 5.

The parasite shown in Fig. 9 was found, as already stated, on December 3rd, in a fly pupa which harboured the larva represented by Fig. 5, and was not more than seven days old.

The most noticeable feature of its development compared with earlier stages was its greatly increased length in proportion to increase in width.

The length of this larva was 0.65 mm. and the width at the posterior end of the oesophagus 0.05 mm. The posterior end of the oesophagus was 0.23 mm. from the anterior end of the body, and about the junction of the first and second third of the oesophagus there was a fairly conspicuous group of rather large nuclei indicating the position of the nerve ring.

Excepting in a general increase in size no marked structural development was observed in the parasites shown in Figs. 10 and 11, which were found on December 7th in fly pupa from the same culture as that which produced the parasites shown in Figs. 5, 6, 7 and 9. These larvae were, therefore, not more than eleven days old.

The smaller parasite (Fig. 10) was 0.8 mm. in length, the larger (Fig. 11) about 0.83 mm. In each the posterior end of the oesophagus was about 0.28 mm. from the anterior end of the body, the maximum width of which was 0.05 mm. The distance of the nerve ring from the anterior end was about 0.1 mm. and that of the anus from the tip of the tail about 0.060 mm.

Further than a general increase in size, no marked development was seen in the larvae shown in Figs. 12, 13, and 13A, as compared with those of earlier stages.

Fig. 12 represents a larva found in a thin-walled spherical cyst in the abdomen of a fly pupa in which the adult fly was almost ready to emerge. The embryo from which it was derived was one of many obtained from ten gravid females on December 21st, and incubated in sterilized faeces at room temperature for a period of six days before being given an opportunity of infecting fly larvae. The fly larvae used in this experiment were about nine days old, and nearly mature when they were liberated on December 27th in the embryo-infected faeces. The resulting pupae were examined on January 3rd; the parasite was therefore about thirteen days old, and had spent not more than seven days of its life within the body of the fly larva.

A larva in the same state of development as that referred to in the preceding paragraph, is shown in larger scale in Figs. 13 and 13A. It was found on November 30th free in a fly pupa from the culture referred to in discussing the embryo shown in Fig. 4. The age of this parasite and the fly pupa was, therefore, nine days, the first 42 hours of which period had been passed by the nematode embryo in sterilized faeces apart from the fly larva.

The length of the parasite was about 1 mm. (1.07 mm.) by 0.05 mm. in width at the posterior end of the oesophagus, which was 0.35 mm. from the anterior end of the body. The intestine was 0.62 mm. in length, followed by a pyriform rectum. The operculum like apex of the rectum was about 0.06 mm. from the tip of the tail and nearly level with the cuticle of the body. The intestine was 0.015 mm. diameter at the base of the oesophagus, increasing to about 0.03 mm. at about 0.07 mm. from its anterior end, then decreasing to about 0.015 mm., which diameter was maintained to near its junction with the rectum.

These parasites were evidently in the stage figured and designated Stage 2 by Ransom (1913, p. 18). It must be remarked, however, that in both parasites referred to in the preceding text nuclei were plainly seen in the rectum (see Figs. 12 and 13A, whereas Ransom remarks of his larva of Stage 2, "nuclei like those seen in the wall of the remainder of the alimentary tract are absent from the rectum."

In adult M. domestica.

Very definite progress in development is seen in the larva represented by Fig. 14, which was found in an adult fly from the same culture as the parasite shown in Fig. 12 and discussed above.

The fly emerged and was examined on January 7th; the parasite was, therefore, seventeen days old. The first six days of its embryonic life were spent in sterilized faeces, with similar embryos only, and not more than eleven days in the body of its intermediate host.

It measured 1.435 mm. in length by about 0.043 mm. in width. The pharnyx, which was 0.0297 mm. in length, was surrounded near the anterior end by a somewhat clear space. The oesophagus was about 0.013 mm. in diameter at the anterior end, increasing very gradually to a minimum diameter of 0.0198 mm. at its base, which was 0.43 mm. from the oral opening. The conspicuous nerve ring, surrounded by numerous nuclei, was about 0.12 mm. from the anterior end of the parasite. A few small nuclei occurred in the body-wall and alimentary tract, but these were few and scattered.

No evidence of a spinous-tipped tail could be seen under the moulting cuticle of this or other larvae of about the same length and condition. This larvae would appear to be in a stage of development near to Stage 3 of Ransom.

Although larvae of this stage are usually found in adult flies, a similar parasite was found in a Musca domestica larva which had

been reared entirely on faeces from the rectum of a horse believed, after a post-mortem examination, to be infected with Habronema muscae only. The fly larva was ten days old at the time of examination, its growth and development having been retarded by low temperature and insufficient nourishment.

In the following stage the vacuole or clear space surrounding the pharynx disappears, but the anal operculum remains, thus agreeing with Ransom's description of his Stage 4 (1913, p. 20). The pharynx is much longer and distinctly wider than in the preceding stage. The oesophagus is also much longer. There is still no indication of the future spinous tip to the tail. A typical larva in this stage of development measured 1.848 mm. in length, by 0.05 mm. in width at the base of the oesophagus. The pharynx was nearly 0.043 mm. in length, and had an oral opening similar to that of the larvae represented in Fig. 15. The nerve ring and base of the oesophagus were 0.12 mm. and 0.64 mm. respectively from the anterior end of the body. The anus was about 0.079 mm. from the tip of the tail, the process of moulting was nearly complete. The worm was found in the abdomen of a fly from the same culture as the parasites shown in Figs. 12 and 14. The fly emerged, and was examined on January 9th; the parasite was, therefore, about nineteen days old, and had lived in its intermediate host for not more than thirteen days.

In the next stage (Ransom's Stage 5), the spines at the tip of the tail are seen under the cuticle and the rectum is distended as in earlier stages, and as recorded by Ransom (1913, p. 21). A larva in this condition was found on the same date in the same culture as that described in the preceding paragraph (i.e., a larva agreeing with Ransom's Stage 4). It measured 2.013 mm. in length by about 0.056 mm. in width at the base of the oesophagus. The pharnyx was nearly 0.043 mm. in length. From the anterior end of the body the nerve ring and base of the oesophagus were distant 0.122 mm. and 0.775 mm. respectively. This worm was found in a cyst in the abdomen, and was about to moult.

Fig. 15 represents a larva in the condition designated Stage 6 by Ransom, which is the final larval stage of Habronema muscae found in the fly. It was reared from a culture of embryos taken from a gravid female on January 11th, and incubated in sterilized faeces for five days (i.e., until January 16th), when the embryo-infected faeces were fed to fly larvae, which hatched on January 7th and emerged as flies on January 30th. The parasite was therefore nineteen days old, not more than fourteen days of which period were spent in its intermediate host.

It measured 2.376 mm. in length by about 0.05 mm. in width at the base of the oesophagus. The cylindrical pharnyx was 0.0495 mm. in length. The nerve ring and the base of the oesophagus were about 0.132 mm. and 0.92 mm. respectively from the anterior end of the body. The anterior end of the oesophagus measured about 0.0115 mm. across, and increased in width somewhat sharply about 0.208 mm. from the anterior end of the body to a maximum width, at the base of the oesophagus, of 0.039 mm. The tail tapers evenly and gradually to the rounded tip, which is covered with small spines (Fig. 16). Similar larvae are commonly found in the head, thorax, and abdomen of flies, and not infrequently within cysts in the last position.

The length of larval H. muscae in the final stage found by the writer in laboratory-bred flies ranges from 2.145 mm. to 2.541 mm., while the range for what are believed to be Habronema muscae (three specimens) found in naturally infected caught flies is 2.178 mm. to 2.244 mm. The range given by Ransom (1913, 21) for the latter is 2.6 mm. to 3.2 mm., the minimum being only 0.04 mm. less than the maximum length known to the writer to be attained by Habronema in the fly. This specimen from a culture artificially infected with embryonic H. muscae (?) was found (November 10th) in a fly five days after its emergence from the pupa.

All stages of the parasite excepting the earliest stage found in the fly larva (see Fig. 4) are known to the writer to sometimes occur in cysts.

Encystment is a condition believed to be assumed by the larval parasite when about to enter a resting period, and not a necessary condition in the process of development.

It has not been considered necessary at the present stage of this investigation to discuss in detail the minute internal developmental changes which take place in the embryonic and larval stages other than as indicated by the variations in the relative lengths and diameters of the parts shown in Table No. 2. The general structure of each stage is shown by the figures and the comments thereon, in this section the term "stage" being employed in a wide sense to indicate obvious steps in the process of development.

Summary and Discussion.

As will be seen, this investigation into the life-history of Habronema muscae is practically a confirmation and extension of the observations by Ransom, to which frequent reference has been

made in the preceding pages, and although the methods employed are entirely different, there are no essential details in the results upon which there is disagreement.

Thus, the embryos passed out in the faeces from the horse are taken up by the larvae of adults of Musca domestica, which have oviposited on the faeces, which remain infective in this respect up to at least eight days after leaving the rectum, the fly larvae being known to react to infection when forty-eight hours up to nine days old, and may be earlier and later. After a slight amount of development in the faeces (Figs. 2 and 3), the embryo of Habronema muscae enters the larva of Musca domestica (see Fig. 4). Then it continues to develop in the fly pupa through the various stages shown in Figs. 5-13A, and in the adult fly as seen in Figs. 14-16, in which condition it is ready to develop in the stomach of the horse, where such stages have been met with.

Ransom (1913, p. 15) has suggested the possibility of infection of the horse in three ways. Firstly, by ingestion of dead infected flies, which he considers perhaps a common source of infection. Secondly, by ingestion of the parasite in water or moist material. Thirdly by ingestion of the parasite after its escape from the fly whilst feeding upon the mucous membrane of the horses' mouth.

His experiments prove that possibly the second theory may account for an occasional infection, but that such infection is not a normal occurrence. My own experiments do not support this second theory at all, since as shown above, I have been unable to obtain any evidence of the escape of the parasite from the fly, though Mr. Bull informs me that he has found such larval parasites to have escaped from flies kept in tubes, whether from living or dead flies was not known.

Concerning the third theory, Ransom says that there is no evidence, as yet, that larval Habronema escape from the fly whilst the latter is feeding upon moist surfaces or matter. The evidence also is still not forthcoming as the result of my experiments.

From these and other observations made during the progress of these investigations, the present writer has no hesitation in expressing the opinion that the ingestion of both living and dead infected flies provides the normal means by which the larval Habronema finds its way into the horse's stomach.

That living flies and those which have recently succumbed are quite commonly ingested by horses from the drinking trough and manger is beyond question. On a frosty morning it is here a common occurrence to find numerous benumbed flies (both Musca

domestica and Stomoxys calcitrans) dislodged from adjacent walls in food and water containers provided for horses.

In the summer months the fodder will be found to be frequented by great numbers of flies of both species, Musca domestica predominating in both cases. That many of these are ingested can scarcely be doubted.

Johnston (1912, p. 76) records the occurrence of larvae of Habronema muscae in Stomoxys calcitrans and Musca domestica in Sydney, and in Musca domestica in Brisbane. If the parasite found by him in Stomoxys calcitrans was of the same species as those found in Musca domestica, the occurrence of the former in Stomoxys calcitrans would appear to be merely a rare accident, inasmuch as on two occasions a massive infection of faeces was supplied by me to both Musca domestica and Stomoxys calcitrans in the same jar, resulting in a heavy infection of the Musca domestica and an entire absence of infection in the fifty Stomoxys calcitrans examined.

B.—Habronema microstoma (Schneider).

1.—Historical.

In the adult stage Habronema microstoma has been known since 1866 as a parasite occurring in the stomach of the horse, but nothing has been known definitely of its life-history.

Von Linstow (1875, pages 195-197) found in the heads of Stomoxys calcitrans a nematode embryo and several larvae which he, assuming them to be of the same species, described and figured under the designation of Filaria stomoxeos. Noè (1913, p. 392) states that Filaria stomoxeos of Linstow is identical with nematodes found by him in Stomoxys, and considers Linstow's species to be an intermediate stage of Filaria labiato-papillosa of cattle (see Ransom, 1913, p. 9). Ransom further remarks that Noè's statements have been commonly accepted, but that it is impossible to judge definitely from the data given whether or not he (Noè) is correct in his opinion as to the identity of the nematodes, and as to their being intermediate stages of Filaria labiato-papillosa.

From Linstow's description Ransom is inclined to consider Filaria stomoxeos a species of Habronema rather than a larval form of Filaria labiato-papillosa, and he suggests the possibility of it being a larval stage of Habronema microstoma.

Other than these suggestions nothing is available as to the life-history of this form.

The Adult.

In the adult stages H. microstoma bears a very close similarity to H. muscae, but the species are distinctly different, and, after a little experience may be easily separated, even when living.

Although well known in Victoria, it is not so frequently met with as its near ally (H. muscae) as will be seen from the results of the census of the parasites found in thirty-nine horses' stomachs examined during the progress of these investigations (c.f. Table No. 9). Whereas H. muscae were found in thirty-three stomachs, H. microstoma were found in only fourteen. In all cases in which both species were found in the same stomach the former greatly outnumbered the latter.

It will be noticed in Table No. 9 that H. microstoma were not found in eleven stomachs examined in the months May—August.

As Ransom has fully described and figured the adult H. microstoma (1913, p. 27), it is unnecessary here to enter into details of the structural and diagnostic characters of the species.

Record of Experiments and Special Observations.

A. To determine the intermediary host or hosts of H. microstoma and the early life-history of the parasite.

The technique followed in these experiments has been fully described in the Introduction to this Report.

Experiment No. 7.

On October 25th embryos from twenty gravid H. microstoma were liberated in sterilized faeces with a number of "clean" four-days' old Musca domestica larvae. Twenty-two of the fly larvae were examined on October 29th and the first two days of November. One of them was found to harbour a single embryo similar to that seen in Figure 20. The remainder of the larvae were not found to be infected. Twenty-seven pupae and twenty-two flies from the same culture jar examined between October 31st and November 7th were not infected.

Experiment No. 8.

Embryos from five worms were liberated in faeces on November 26th, with a number of Musca domestica larvae then three days old. Five larvae, 57 pupae and 35 adult flies were examined between November 29th and December 11th, of which only one larva was found to be infected (November 29th). The embryo found in

this larva agreed with the one found in similar circumstances in Experiment No. 7, and with that found under similar conditions in Experiment No. 12 (see Fig. 20).

Experiment No. 9.

This experiment, commenced on November 28th, was similar to No. 1, excepting that the embryos were obtained from three worms only. Between December 4th and December 12th, 1 larva, 60 pupae and 25 adult flies were examined, none of which was found to be infected.

Experiment No. 10.

On December 3rd Experiments Nos. 7 and 9 were repeated, with embryos from seven worms fed to four-days-old fly larvae. Subsequently 15 pupae and 55 adult flies of Musca domestica were examined (December 17th and 20th), with negative results.

On December 18th, finding that the faecal matter was still heavily infected with living embryos of H. microstoma, then enclosed in sheaths, a number of two days old larval Stomoxys calcitrans were liberated in it. Forty-four adult Stomoxys flies, resulting from these larvae, were examined between January 7th and 10th, with the result that 21 were found to harbour from one to three larval Habronema each, while the remaining 23 were negative.

As will be seen later (Experiment No. 13), the difference in age of the larvae to which the embryos were fed cannot be supposed to have had any influence on the result here recorded for Experiment 10.

Experiment No. 11.

Embryos from about 30 gravid worms were liberated in faeces containing numerous five and six days old Musca domestica larvae on December 14th. Sixty-eight of the resulting fly pupae and adults were examined between December 17th and 24th, none of which was found to be infected.

Experiment No. 12.

Embryos from six gravid worms were liberated in faeces on December 21st, and incubated at room temperature until December 24th, when a number of Stomoxys larvae, then six days old, were added to the culture. On December 27th a fly larva was examined and found to harbour one embryo (see Fig. 20) comparable in structure with those found in Experiments 7 and 8, with M. domestica larva. Five pupae were examined on January 3rd and 4th,

and sixteen adult flies from January 10th to 16th, all of which were infected, the number of larval nematodes in each varying between 4 and 50, averaging about 25.

Experiment No. 13.

After a period of forty-eight hours' incubation at room temperature, a culture of previously sterilized faeces containing embryos from twenty specimens of Habronema microstoma was infected on January 16th, with nine-day-old larvae of Musca domestica, and with Stomoxys calcitrans larvae of the same age. The majority of the Musca larvae and some of the Stomoxys had already ceased feeding, consequently infection of the former was not expected. Only two Musca domestica flies emerged (January 27th and 28th), neither of which harboured nematode larvae. On the other hand, two Stomoxys larvae which were examined on January 2th, harboured four and five parasites respectively, while each of three pupa examined on January 23rd and 29th contained upwards of thirty-five parasites. Other Stomoxys pupae were examined between these dates, each of which was heavily infected.

Experiment No. 14.

Embryos from six worms were liberated in sterilized faeces on January 22nd, and incubated at room temperature until January 29th, when Musca domestica larvae, then five days old, were added to the culture. Twenty-three flies emerged on February 11th and 12th, of which number one only was infected. This parasite (Fig. 26) was evidently malformed.

B. To determine the frequency of larval Habronema in Stomoxys calcitrans, and their abundance and location in the body of the intermediate host.

(i.) Free or Caught Flies.—During the period May to November 63 flies, 10 pupae and 12 larvae of Stomoxys calcitrans were collected in the Institute grounds and examined for the presence of Habronema. Of this number only one fly was found to be infected (May 4th). The parasite, which was located in the abdomen, measured about 1.5 mm. in length and agreed with typical examples of larvae of H. microstoma, as found in flies bred and infected in the laboratory.

(ii.) Laboratory bred flies showed a very high percentage of infection, as will be seen by reference to Experiments No. 10, page

31; No. 11, page 31; No. 12, page 31; No. 13, page 32; No. 14, page 32.

In the first of these experiments (No. 10), 47.7% of the flies examined were infected, and in the remaining four 100% of those examined harboured from a few to ·60 parasites each. In most cases the majority of the parasites were located in the proboscis and head, particularly in heavily infected individuals. The following record of the location of parsites is fairly typical:—Fly (a) harboured 45 parasites, of which 10 were located in the proboscis, 20 in the head, and 15 in the thorax and abdomen; fly (b) harboured 36 parasites, of which 15 were found in the proboscis and 21 in the head; fly (c) harboured 27 parasites, of which 12 were in the proboscis, 14 in the head, and 1 in the thorax; fly (d) harboured 30 parasites, of which 15 were in the proboscis and head, and 15 in the thorax and abdomen; fly (e) harboured 60 parasites, of which 35 were found in the proboscis and head and 25 in the thorax and abdomen.

Encysted larvae are frequently found in the abdomen of the infected fly. Generally a cyst contains a single larva, and there may be several cysts in one fly. Larger cysts containing more than one parasite are seldom found. One Stomoxys fly, however, which was found to harbour over 60 parasites, contained three cysts in the abdomen, one of which enclosed one parasite, one five parasites, and one seven parasites.

C. To determine the viability of embryonic Habronema microstoma in faeces.

It has been shown (Experiment No. 10, p. 31, that embryonic H. microstoma may survive for a period of fifteen days in sterilized faeces and still remain capable of infecting fly larvae. In this experiment embryos were incubated in faeces from December 3rd to December 18th, before being exposed to ingestion by Stomoxys larvae. All embryos found on the latter date were enclosed in sheaths. The resulting flies were examined between January 7th and 10th, when over 47% were found to harbour from one to three parasites each.

Under favourable natural conditions the period of viability is possibly quite as long—indeed there is some reason to believe that a fairly long period of viability in faeces is necessary for the propagation of the species. This aspect of the life-history of H. microstoma is referred to more fully elsewhere in this report. (See page 44).

D. To determine the period of survival of larvae removed from flies.

During the afternoon of January 16th, 25 H. microstoma larvae from the heads of two Stomoxys flies were placed in normal saline contained in a small covered Petri-dish and examined daily until January 20th. Two were dead on January 17th, five on January 18th, twelve on January 19th, four on January 20th, leaving two living at noon on the last date. No examination was made on January 21st, but both were found dead early on January 22nd.

E. To determine the period of survival of larvae in dead flies.

A Stomoxys fly which emerged on January 14th was kept in a wire-gauze cage until January 16th, when it died. It was then placed on moistened paper in a covered Petri-dish, where it remained for forty-eight hours. On dissection the head and the proboscis were found to contain 35 dead larvae.

F. To determine the possibility of escape of larval H. microstoma from flies.

Stomoxys flies were frequently placed in moist, and in dry, tubes for periods up to thirty hours, to determine whether under such conditions the parasite would escape either before or after the death of insects. Although the flies were subsequently proved to be heavily infected, in no instance were parasites found free in the tubes.

Time has not permitted, so far, of much experimental work to determine whether or not larval H. microstoma may be carried into a wound made by a Stomoxys fly during feeding operation, but on January 12th attempts were made to induce Stomoxys flies (afterwards proved infected) to bite horses by placing them on various parts of the skin, including a bare patch on the back. In some cases there was a determined attempt on the part of the flies to bite, but strangely enough none succeeded in penetrating the skin. Two of these experimental flies were subsequently dissected and found to harbour 12 and 15 parasites respectively in the proboscis and 14 and 25 respectively in other parts of the head.

The escape of larvae from freshly severed heads in normal saline has been observed frequently. The exit of the parasite is made very rapidly, either from the tip of the proboscis, or by forcing its way out between the labium and the labrum-epipharynx. Photo-

micrographic Figs. 34 and 35 show larvae escaping in both ways.

It seems possible in view of the above facts and the well known piercing power of the proboscis in Stomoxys calcitrans that the failure of the specimens to pierce the skin in the above experiment was due to the proboscis being clogged by the larval parasites, twelve in one case and fifteen in the other.

G. To determine whether from a mixed infection of Habronema muscae and Habronema microstoma in sterilized faeces any selective action is present between the parasites and a particular species of intermediate host.

All the evidence adduced as a result of the experiments and observations recorded in the preceding pages of this report is in the direction of establishing the fact—(1) that Habronema muscae has Musca domestica for its only intermediary host, (2) that H. microstoma has Stomoxys calcitrans for its principal intermediary, (3) that Musca domestica may act, very rarely and in small measure—under experimental conditions, at any rate—as an alternate intermediary host for H. microstoma.

It appeared desirable therefore to carry out further experiments to determine the selective activity (if any) shown by Habronema embryos of a particular species for a particular species of intermediary, and especially the relationship of Stomoxys calcitrans to Habronema musca and the relationship of Musca domestica to Habronema microstoma when given a free choice. With this object in view the following experiments were carried out:—

Experiment No. 15.

On January 21st embryos from three gravid females of H. muscae and H. microstoma were liberated in sterilized faeces, and on the following and subsequent days larval Musca domestica and Stomoxys calcitrans, then three days old, were fed upon the infected matter. The first 28 Musca domestica flies emerged on February 4th, of which 15 were infected and 13 were free from parasites, the number of parasites in infected flies varying from one only in each of seven flies to four in each of three flies.

The first six Stomoxys flies emerged on February 11th, all of which were found to be heavily infected, i.e., not less than 60 parasites in each. Details and measurements of some of these larvae are given in Tables 5 and 6.

In Table 5 particulars are given of six larvae from Musca domestica flies (February 4th). The measurements of specimens

1 and 2, when compared with those of undoubted H. muscae in the same stage of development (Table No. 1), agree closely with that species, to which they undoubtedly belong.

On the other hand, the measurements of Specimens 3-6 (Table No. 5) do not agree with those of Specimens 1 and 2 of the same table, but they agree fairly closely with undoubted specimens of H. microstoma in a similar stage of development (see Table 2), and there is no doubt in the writer's mind that they are referable to the last-named species and to the stage of that species preceding the appearance of spines under the cuticle at the tip of the tail.

It was not noted whether both species of Habronema occurred in any individual fly. In Table No. 6 measurements and details are given of eleven larval Habronema from Stomoxys calcitrans flies bred from the same culture (February 11th). A comparison of these measurements with those of undoubted H. microstoma (Table No. 2), and H. muscae (Table 1) leaves little doubt but that they are referable to the former species only.

Experiment No. 16.

Embryos from gravid H. muscae and H. microstoma were liberated in sterilized faeces on January 11 and 14th respectively, and incubated until January 16th. On January 14th and subsequent days larval Musca domestica and Stomoxys calcitrans, which hatched on January 7th, were fed upon the infected matter and of the resulting flies one M. domestica and twenty S. calcitrans were examined and found to be infected on January 29th and 30th.

The measurements of four Habronema larvae from the Musca domestica fly are given in Table No. 7, the measurements of the remaining three being omitted on account of their agreement with Specimen No. 2 in the above table. It will be seen by comparing these measurements with those shown in Tables Nos. 1 and 2, that the larvae found in this fly were almost certainly H. muscae. If a further comparison is made between Table 8, which gives the measurements of 6 Habronema larvae from Stomoxys flies (30th January), and Tables Nos. 1, 2 and 7, it will be found that the evidence is strongly in favour of these larvae (Table 8) being referable to H. microstoma.

These experiments confirm the fact that the final larval stage of H. microstoma in the fly may be attained in the body of Musca domestica as well as in Stomoxys calcitrans, while previous experiments (7, 8, and 14) seemed to show that such was not the case.

Development.

The eggs and embryos of Habronema microstoma as found in the adult worm are illustrated in Fig. 18. The egg (Fig. 18a) measures from 0.04 mm. to 0.05 mm. in length by about 0.01 mm. in diameter, and is similar to that of H. muscae. Fig. 18, b and c, show progressive stages in which the developing embryo is clearly seen within the egg-shell. The final stage (Fig. 18 d), within the uterus of the female is reached when the embryo attains a length of from 0.085 to 0.105 mm., and a diameter of from .0055 mm. to 0.0075 mm. At 0.035 mm. to 0.045 mm. from the anterior end there is a more or less conspicuous nucleus and frequently two or three smaller nuclei may be made out nearer the posterior end. The form of the anterior end can be made out only with difficulty. There appears to be a rudimentary pharynx and a small horn-like process in front of the head, as in H. muscae, but the clear space sometimes seen surrounding what appears to be the pharynx in that species has not been observed in H. microstoma.

Development of the embryo in faeces.

There can be little doubt but that embryos leave the horse in the faeces, but it is not known whether they undergo any further development during their passage through the intestines. Definite development does take place, however, in the faeces after egestion, but whether this development is necessary before the embryo is capable of entering the fly larvae is not yet known, owing to the great difficulty of being sure of the species of the larvae found in the fresh faeces, material not having been available from a horse which could afterwards be known to have contained H. microstoma only.

Fig. 19 shows an embryo which was taken from the uterus of an adult worm on December 21st, and incubated in sterilized faeces until December 26th (see Experiment No. 12, p 31). The parasite, which was very active, was at the end of this five days' incubation 0.115 mm. long by 0.007 mm. wide. About 0.026 mm. from the anterior end there was a group of small nuclei which were not seen in other parts of the body, and at 0.053 mm. from the anterior end there was a much larger and more conspicuous nucleus. The sheath which enveloped it was very thin and elastic.

In another similar culture (Experiment No. 8, p. 30), in which the embryos had been incubated for a period of three days (Novem-

ber 26th to 29th), active embryos were found which measured about 0.1 mm. long by 0.0065 mm. wide. The group of small nuclei observed in the larger embryo referred to above were not made out, but a fairly large and conspicuous nucleus was seen in each about 0.045 mm. from the anterior end. The majority of these embryos were enveloped in sheaths, but others were free. On the same day and from the same culture a Musca domestica larva was found to be infected with an embryo measuring 0.099 mm. long by 0.0065 mm. wide, with a nucleus at 0.048 mm. from the anterior end, but otherwise agreeing with the forms found free in the faeces.

On December 27th an embryo (Fig. 20) was found in a Stomoxys larva which agreed very closely with the one shown in Fig. 19. Both embryos were from the same culture (i.e., Experiment No. 12, p. 31), but whereas the later (Fig. 19) was five days old, and had lived in faecal matter only, the former (Fig. 20) was six days old, and may have been harboured within the fly larva for not more than three days.,

The parasite shown in Fig. 20 measured about 0.115 mm. long by about 0.0066 mm. wide. A very large nucleus occurred at about 0.039 mm. from the anterior end, and numerous small ones could be seen occupying the middle line of the body for the greater part of its length. The tail was usually carried bent sharply over, but during the frequent snake-like movements of the body it was seen to be capable of the freest action. This embryo, like the other from the same culture, was enclosed in a sheath.

Succeeding stages in the development of the parasite are shown in Figs. 21, 22, and 23. These three, in addition to two embryos similar to the one represented in Fig. 20, were found on January 24th in a Stomoxys larva from the culture referred to in Experiment No. 13, p. 32. The latter two were located in the alimentary tract, and were not enclosed in sheaths, the others, Figs. 21, 22 and 23, were found in the fat-body separating the body wall from the alimentary tract.

The parasite shown in Fig. 21 was about 0.138 mm. long by about 0.02 mm. wide at the anus. The process at the anterior end noted in earlier stages was still evident. An oral opening could not be made out, but a clear space at the anterior end of the body indicated the presence of a pharynx. There was no visible alimentary tract, the whole of the body being apparently composed of a mass of nuclei of varying sizes, those in the anterior half being largest. The anal opening was closed by a rounded projection. Only a portion of the rectum could be seen clearly. The tail, which

was curved, tapered very abruptly, and ended in a finely pointed tip.

Fig. 22 shows a parasite evidently in a slightly more advanced state of development. It measured about 0.15 mm. long by 0.025 mm. wide at the anus, and was enclosed in a spherical cyst. The process at the anterior end, previously referred to, was still to be seen, although a change in the general outline of that end was observed. The clear space seen at the anterior end of the body in the preceding stage (Fig. 21) was not made out. The whole of the body was composed of nuclei, those about the middle being the largest. Excepting the rectum, which was large, there was no evidence of an alimentary tract. The rectum was much distended, but the anus, which was 0.026 mm. from the tip of the tail, was closed as in the preceding stage.

The larva seen in Fig. 23 showed still further development. In this the outline of the anterior end was still more irregular than in the preceding stage. A well-defined mass of large nuclei occupied the greater part of the body from near the anterior end posteriorly for a length of 0.082 mm. From the posterior end of this mass to the rectum these nuclei were somewhat smaller and more scattered and the rectum was rather smaller than in the preceding stage. The anus was 0.026 mm. from the tip of the tail, and was closed by a rounded projection as in earlier stages. The length of the parasite was about 0.175 mm.

Reference to Experiment No. 13, page 32, shows that these five parasites were ten days old when examined, and that the period of their existence in the Stomoxys larva could not have exceeded eight days. Presumably the two least developed forms found their way into the body of the intermediate host later than the three more advanced ones.

Larval stages comparable with those shown in Figs. 21, 22 and 23 are not known in H. muscae, but probably they do occur between the stages illustrated by Fig. 4 and Fig. 5.

The earliest stage in which a definite oral opening is known to occur is shown in Figs 24 and 25. This larva, together with several others in the same stage of development, was found on January 23rd in a newly-formed pupa from the same culture as the larvae shown in Figs, 21, 22, and 23 (i.e., Experiment No. 13). It was therefore nine days old, not more than seven days of which period had been spent in the body of the fly larva. It measured 0.24 mm. long. The oral cavity was apparently closed at its junction with the pharynx (?). The body, which was 0.24 mm. long, was narrowest

at the anterior end, and increased gradually to the anus, at which point it was 0.05 mm. in diameter. The tip of tail which was bluntly pointed was about 0.05 mm. from the operculum-like projection of the anus. This larva was apparently somewhat less developed than the larval H. muscae shown in Fig. 5, which measured 0.25 mm. long, and which was probably some days younger (c.f. page 22).

Fig. 26 shows a larva in a somewhat similar stage of development, which was found on February 12th in the abdomen of a Musca domestica fly (see Experiment No. 14, page 32). It measured 0.25 mm. long by 0.049 mm. wide. The oesophagus, which was considerably twisted, joined the intestine about 0.082 mm. from the rectum. The anterior end was partly enveloped in a portion of the cast-off cuticle, a portion of which adhered also to the posterior end. The rounded tail, the general appearance of the parasite, and the occurrence of such an undeveloped stage in a mature fly of a species not apparently normal for this worm suggests that this specimen was an abnormality.

Figs. 27 and 28 show the next step in the development of the larvae. The lower part of the pharynx is now surrounded by a clear space or vacuole, a feature which has not been observed in larval H. musca of less than about 0.65 mm. in length, whereas the worm figured in Figs. 27 and 28 measured only 0.247 mm. long by 0.04 mm. wide at the rectum. The form of the oesophagus and intestine are now well defined, and the large nuclei have almost disappeared from the alimentary tract. Small nuclei only are dispersed through the oesophagus, intestine, and body wall, but those in the rectum and posterior end are considerably larger. The body is relatively longer and narrower than in earlier stages.

At the base of the oesophagus, which was 0.1 mm. from the anterior end, the diameter of the body was 0.036 mm. The anus, still closed as in the earlier stages, was 0.033 mm. from the tip of the tail. That the worm figured was undergoing a moult was shown by the presence of the partly discarded cuticular lining of the oral cavity.

This parasite was found on January 4th in a Stomoxys pupa which had developed in the same culture as the embryo illustrated by Fig. 20 (i.e., Experiment No. 12, page 31). It was therefore fourteen days old, and had been harboured by the intermediate host for a period not exceeding eleven days. This pupa contained upwards of fifteen larval Habronema microstoma, including two

larvae similar in all respects to the one just described and the parasite illustrated in Fig. 29.

The larva illustrated in Fig. 29 was relatively much longer and narrower than that shown in Figs. 27 and 28, but there was otherwise little marked developmental change. The worm figured (Fig. 29), measured about 0.435 mm. long by 0.04 mm. wide at the base of the oesophagus and at the rectum. Scattered nuclei were seen in the oesophagus, intestine and body wall, those in the anterior portion of the body being few and scattered. At about 0.07 mm. from the anterior end there was some indication of a nerve ring. The base of the oesophagus was 0.165 mm. from the anterior end of the body, and at its base there was a slight dilation of the intestine. The anus was similar to earlier stages, but the tail was distinctly rounded. This larva is comparable with the stage of H. muscae represented in Fig. 9; the latter, however, was 0.115 mm. longer than the present specimen of H. microstoma.

The larva shown in Figure 30, although somewhat shorter than the preceding one, was evidently in a slightly more advanced stage of development. It measured 0.34 mm. long by 0.056 mm. wide at the rectum. The base of the oesophagus was 0.2 mm. from the anterior end, at which point the body was 0.05 mm. in diameter. The tip of the tail was 0.046 mm. from the anus. This larva was one of thirty or more found on January 4th, in the head of a Stomoxys pupa from the same culture as the two preceding ones (Experiment No. 12, page 26).

The next stage known to the writer is shown in Fig. 31. The worm figured was one of 35 larvae found in a Stomoxys fly (January 10th) from the same culture as the preceding stages (i.e., Experiment No. 12, p. 31). It measured 0.95 mm. long by 0.04 mm. wide at the base of the oesophagus. The base of the pharnyx and oesophagus were respectively 0.03 mm. and 0.38 mm. from the anterior end of the body. The anterior end of the oesophagus was about 0.01 mm. in diameter, increasing at the base to about 0.016 mm. At about 0.092 mm. from the anterior end there was a conspicuous nerve ring followed by a group of large nuclei. The anus, still closed, was about 0.043 mm. from the tip of the tail. The moulting cuticle completely enveloped the worm. This parasite was twenty days old, not more than seventeen days of which period may have been passed within the body of the fly, and it most resembled that stage of H. muscae illustrated by Fig. 14; the latter measured, however, 0.485 mm. longer than the former, but was apparently less developed. As previously stated (page 25), it was

seventeen days old, and had lived in the body of the fly not more than eleven days.

After undergoing at least another moult the minute spines at the tip of the tail are seen under the cuticle. The parasite now measures from 1.419 mm. to 1.550 mm. in length. This stage, which is comparable with Ransom's 5th stage of Habronema muscae, is generally found in the head or abdomen of pupae in an advanced stage of development.

Numerous larval parasites in this stage of development were found in a pupa on January 29th, in a culture (Experiment No. 13, page 32), which produced also the parasites of Figs. 21, 22 and 23. Reference to this experiment will show that the larvae were fifteen days old, and that not more than thirteen days of this period could have been lived within the body of the developing fly. A typical example measured 1.485 mm. long by 0.049 mm. wide at the base of the oesophagus, i.e., about 0.68 mm. from the anterior end, and about 0.033 mm. wide at the anus.

The oesophagus was 0.013 mm. in diameter at the anterior end, and increased to 0.030 mm. in diameter at its base. The nerve-ring was about 0.1 mm. from the anterior end and the closed anus about 0.059 mm. from the tip of the tail. The moulting cuticle adhered somewhat closely to the body.

After this moult is completed, the spines are evident at the tip of tail, and the anus is no longer closed by the rounded projection seen in earlier stages. Fig. 32 shows the anterior end of a worm in this stage of development, which was found in the proboscis of a Stomoxys fly on January 12th. The parasite was reared from the same culture as those shown in the three preceding figures (Experiment No. 12), and was therefore twenty-two days old, not more than nineteen days of which period may have been spent within the intermediate host. It measured 1.560 mm. long by 0.0495 mm. wide at the base of the oesophagus, and 0.0297 mm. wide at the anal opening. The length of the pharynx was about 0.049 mm. The nerve ring and base of the oesophagus were respectively 0.1 mm. and 0.69 mm. from the anterior end. The oesophagus was 0.0135 mm. in diameter at its base. The anterior one-sixth was of fairly uniform diameter, but about 0.11 mm. from its commencement a marked increase in thickness occurred which was maintained through its remaining length.

The tip of the tail, which was about 0.069 mm. from the anal opening, was bluntly rounded, and ornamented with minute spines.

This is apparently the final larval stage of H. microstoma in the body of the fly, and the stage comparable with Ransom's 6th stage of H. muscae. Although larger larvae are found in flies, no further developmental changes, other than a general increase in size, have been observed in them. It is presumed, therefore, that in this stage the parasite is ingested by the horse, and thereafter continues its development in the stomach of the definitive host.

Fig. 33 illustrates the posterior end of a parasite found on the same day and in the same culture as the larvae shown in Fig. 32. Although the former was somewhat larger (see Table 2, Specimen 5), both were evidently in the same stage of development.

The maximum length known to the writer to be attained by the larval worm within the fly is 1.815 mm. (see Table 2, Specimen 1). A larvae of this length was found on January 16th in a fly which emerged two days previously from the same culture as the two last mentioned parasites, i.e., Experiment No. 12. Other larvae from the same fly measured from 1.584 mm. to 1.600.

The final larval stage of H. microstoma in the body of the Stomoxys fly measures from 1.570 mm. to 1.815 mm. long, and although considerably shorter than the final larval stage of H. muscae in the body of Musca domestica, it is in the same state of advancement as the latter, as shown, e.g., by the presence of the characteristic spinous-tipped tail.

Excepting only the earliest stage in the body of the fly-larvae (c.f. Fig. 20), all the larval stages of H. microstoma known to the writer occur sometimes in cysts.

Summary and Discussion.

From an analysis of the experiments carried out to determine the relationship of Musca domestica and Stomoxys calcitrans to the embryos of H. microstoma, it will be seen that Musca domestica exclusively was used in five experiments. In two cases no infection took place, while in the remaining three cases a total of only three individuals became infected, each with a single parasite. In all, 419 Musca domestica larvae, pupae, and flies were examined, with the result stated. In one of these experiments Musca domestica larvae failed to become infected in a culture, which subsequently infected 100% of the Stomoxys calcitrans examined; certainly the two species of fly larvae were at different ages, but other experiments with larvae of the same age of the two species together, would lead one to believe that the age of the fly larvae had no influence at

all on the result, as the worm larvae were actively alive. Stomoxys calcitrans exclusively was used in one experiment, with the result that 100% of the individuals subsequently examined were found to be more or less heavily infected. In another experiment both species of fly larvae were introduced at the same time to a culture of H. microstoma, with the result that 100% of the Stomoxys were heavily infected, whilst the Muscà domestica were negative. In all, 71 Stomoxys larvae, pupae and adult flies were examined, of which number 48 were infected.

In the other two experiments (Nos. 15 and 16), a double culture, i.e., of Habronema muscae and of Habronema microstoma, was given as food to Musca domestica and Stomoxys calcitrans, in the same cage. Both of these experiments show undoubtedly that while Habronema muscae only occurs in Musca domestica, even when Stomoxys calcitrans is in the presence of an intense infection, Habronema microstoma occurs almost entirely in Stomoxys calcitrans, but also rarely in Musca domestica.

Upon the results of these experiments, supported by the finding of what was almost certainly a larval H. microstoma in a naturally infected Stomoxys fly (c.f. page 32), and further supported by the results of the experiments recorded on pages 16. 17, 18, 31 and 32 of this Report, the writer bases his conclusion that Stomoxys calcitrans is the principal intermediary host of H. microstoma, and that Musca domestica only occasionally (possibly only accidentally) acts as an intermediary.

In arriving at the first conclusion the writer has not lost sight of the fact that deposits of fresh horse faeces are not the usual breeding place of Stomoxys calcitrans. It is well known that this fly breeds frequently, if not generally, in decaying grass, straw, and similar matter, and also in loose soil contaminated by stable drainage. The larvae and pupae are to be found commonly, however, in the older portions of manure heaps, and in such situations as are to be found in crowded horse yards. It has been proved during these investigations, that under certain conditions, embryonic H. microstoma remain infective in faeces for a period of at least fifteen days.

The fact that fresh faeces are not usually used as a breeding ground by Stomoxys calcitrans offers no obstacle to Stomoxys calcitrans acting as a natural intermediary host of H. microstoma; rather, this with other facts mentioned above, suggests the only feasible explanation of some phenomena in the life of this form which do not appear to be otherwise explainable, namely, the

lengthy period of viability of the embryo, the relative scarcity in horses' stomachs of the adult stages of H. microstoma as compared with H. muscae and the apparent seasonal occurrence of the former species, from my observations, confined to a period from September to January.

Unlike the adult Musca domestica flies, which are to be found here more or less plentifully throughout the year, Stomoxys flies are extremely scarce during the winter and spring. These flies generally appear in numbers during the latter part of December, becomes increasingly numerous in January, February and March, and gradually disappear until very few remain in June. Why none of this species (H. microstoma) was found in the animals post-mortemed during late January to early March is not easy of explanation, since the fly host has been numerous, and the season very mild, and the horses examined came from various locations.

This investigation shows that the life-history of H. microstoma is somewhat similar to that of H. muscae, although the principal intermediary host is a different species of fly. Briefly summarised, the life-history is as follows :—The embryos passed out in the faeces from the horse are taken up by the larvae of Stomoxys calcitrans which have oviposited on the faeces. The faeces remain infective in this respect up to at least fifteen days, the fly-larvae being known to react to infection when two days up to nine days old, and possibly earlier and later. After apparently undergoing a slight development in the faeces (Fig. 19), the embryo of H. microstoma (Fig. 20) enters the larva of Stomoxys calcitrans (or rarely and possibly accidentally the larva of Musca domestica), where it continues to develop through the stages shown in Figs. 21-23.

Development continues in the pupa through the stages shown in Figs. 24-30; and in the adult fly, as seen in Figs. 31-33, in which condition it is ready to develop in the stomach of the horse, where it reaches maturity. Doubtless, infection of the alimentary canal of the horse is brought about at least in part by ingestion of living and dead infected flies.

Whether a living Stomoxys infected with H. microstoma is able to infect the definitive host with this parasite by means of direct inoculation into the skin yet remains to be proved. So far as my experiments go it has not done so, though this may have been due to a clogging of the proboscis by the fifteen and twenty parasites present in it in the two cases specially examined, preventing it from properly piercing the skin, over-infection thus defeating the object of infection of the intermediary.

C.—Habronema megastoma (Rudolphi, 1819).

1.—Historical.

As stated in the Introduction to Part I. of this report nothing definite appears to have been recorded of the life-history of H. megastoma, either in Australia or elsewhere.

Apparently (Railliet, 1916, p. 102) some reference is made to the larvae of this worm by Ercolani, 1859, but the paper has not been available to me for study.

Railliet (1895, p. 535) states that the life-history of this species is unknown, but that there is reason to suppose that the intermediate host is an insect found in fodder. The same author (page 534) states further that Chabert in 1782 recorded H. megastoma as the causative agent of tumours in the stomach of the horse.

2.—The Adult.

The adult of H. megastoma is easily separated from its congeners, H. muscae and H. microstoma, by its smaller size, and the very distinctive form of the anterior end. The worm, however, is so well known that it is quite unnecessary here to describe it in detail.

It would appear from the writer's observations that the adult stages of H. megastoma occur naturally only in tumours in the definitive host and that their rare occurrence on the external surface of the tumour or adjacent membrane is due to their escape from their natural surroundings after the death of the host. The occurrence within the tumours of young larvae, i.e., those in the final stage of development attained in the body of the fly will be referred to later on.

A census of the nematode parasites found in thirty-nine horses' stomachs examined during these investigations shows that nineteen stomachs contained well-developed tumours of H. megastoma (c.f. Table 9).

The adults are also known to occur in the splenic abscesses which appear to have become more common of recent years, and to be responsible for a considerable increase of mortality in horses in certain seasons and certain districts in South-Eastern Australia.

3.—Record of Experiments.

The technique employed in these experiments has been fully described on pages 12-15.

In the whole thirty-nine horses' stomachs examined, of which nineteen contained tumours of H. megastoma, I have never been able to find any stage, adult or otherwise, of H. muscae or H. microstoma associated with such tumours—which is in harmony with the commonly accepted statement that these tumours are due to H. megastoma. For this reason, therefore, it has been considered perfectly safe for experimental purposes to use the contents of such tumours to infect sterile faeces with the eggs and embryos of H. megastoma.

A. To determine the intermediary host or hosts of H. megastoma and the early life-history of the parasite.

Experiment No. 17.

On October 25th the contents of a stomach tumour or nodule containing embryos were mixed with sterilized normal saline and sterilized faeces, and without a preliminary period of incubation fed to four-days-old larvae of Musca domestica. All seventeen of the resulting adult flies were examined on November 6th, 7th and 8th, of which number six contained from one parasite in one fly to eight parasites in three other flies. These parasites measured from 0.21 mm. to 0.95 mm. long.

Experiment No. 18.

A similar experiment to No. 1 was commenced on November 26th with three-days-old Musca domestica larvae. Three days later a portion of the faecal matter was examined, and found to contain a few living embryos. Subsequently (November 29th to December 10th), the resulting larvae, pupae and flies, fifty-two in all, were examined with negative results.

Experiment No. 19.

The contents of a stomach tumour were mixed with saline and sterilized faeces on December 3rd, and incubated at a temperature of 22°C.—27°C. for seven days. On December 10th and subsequently, five-days-old larvae of Musca domestica were fed on the infected matter. On December 18th living embryos were still found in the faeces. Between December 17th and 21st, 8 larvae, 5 pupae and 77 adult flies were examined, of which number 3 larvae and 42 flies were found to contain larval parasites. One or two parasites, measuring 0.32 mm.-0.5 mm. long, were found in most of the flies, but in one case, ten parasites measuring about 0.86 mm. long, were found, eight of which were encysted.

Experiment No. 20.

This culture was prepared on December 13th in the same manner as the three preceding ones. Musca domestica larvae (three days-old) were fed upon the infected matter from the time of its preparation (December 13th) until they pupated, or were dissected. On December 21st and five succeeding days a total of 36 larvae, 15 pupae, and 33 adult flies were examined, of which number 13 flies only were found to be infected with from 1 to 16 larval parasites each. About 50% of the larval parasites were encysted.

Experiment No. 21.

This culture was prepared on December 19th in the same manner as the preceding ones. On the same day the infected material was given as food to "clean," two-days-old larvae of Stomoxys calcitrans, and on January 4th and 5th 55 adult flies resulted, and were examined, with negative results.

Experiment No. 22.

Embryos from thirty or more gravid H. megastoma were mixed with saline and sterile faeces on January 23rd, and incubated at room temperature until January 29th, on which date living embryos were found in culture. Five-days-old larvae of Stomoxys calcitrans were fed upon the infected matter on January 29th and subsequent days, and on February 14th 27 of the resulting adult flies were examined, none of which was infected.

B. To determine the frequency of larval Habronema megastoma in Musca domestica and their abundance and location in the body of the host.

(i.) Free or caught flies.—Larval H. megastoma have not been identified in naturally bred flies that have been caught.

(ii.) Laboratory bred flies showed a lower percentage of infection than with either H. muscae or H. microstoma, as will be seen by reference to Experiments No. 17, page 47, No. 19, page 47, and No. 20, page 48.

In the first of these experiments (No. 17) about 35% of the flies examined were infected; the number of parasites found in each Musca domestica fly varied from 1-8, the average being two. The head and thorax were the only regions of the body infected.

In the second positive experiment (No. 19), 50% of the larvae and flies examined were infected, the number of parasites in each varying from one to ten. No embryos could be found in the pupae. The abdomen only of adult flies was infected, and in one of these eight of the total number of ten parasites were found in cysts.

In the third positive experiment (No. 20), about 15.5% of the flies (adults only) were infected with from one to sixteen parasites each, all of which were located in the abdomen only. Of the total number of parasites from this culture about 50 per cent. were encysted.

The negative results obtained in Experiment No. 18 are very strange in view of the fact that the only definite difference between this and Experiment No. 17, which was distinctly positive, was in the younger age (three days) of the fly larvae used in Experiment No. 18, and in the fact that examination of the larvae, pupae, and flies was commenced at three days instead of eleven days, though in both cases it was continued up to fourteen days. The fact, however, that only a few living worm embryos were found in the culture three days after the commencement of the experiment suggests that either the infestation of the culture was not sufficiently massive, or that some unknown occurrence had killed off the majority of the worm embryos.

C. To determine the viability of embryonic Habronema megastoma in faeces.

Experiment No. 19, page 45, shows that embryonic H. megastoma may survive for a period of at least fifteen days in sterilized faeces and remain infective to larvae of Musca domestica for a period of at least seven days. Further, if one may judge by analogy with H. microstoma the survival of H. megastoma larvae for probably at least fifteen days in the sterile faeces suggests that such infected faeces may remain infective for the full fifteen days. At the end of this fifteen days, during which the embryos in this culture were incubated at a temperature of 22°C., 27°C., they were found to be in the condition shown in Fig. 38, a and b.

Reference to experiments with embryonic H. muscae and H. microstoma shows that the periods of viability in these species was not less than eight (the longest period tested) and fifteen days respectively.

D. To determine the period of survival of larvae removed from flies.

At 4. p.m. on December 21st, six of the encysted H. megastoma larvae referred to under Experiment 19, page 47, were placed in sterilized normal saline, contained in a covered Petri dish. All were living on the following afternoon, three died before 10 a.m. of the next morning, December 23rd (forty-two hours), two died before 10.30 a.m. on the next day (December 24th), and the last died before 4.30 on that afternoon, a maximum of four days. These parasites were in the stage of development shown in Fig. 45.

On December 24th (noon), eleven larval H. megastoma, from Experiment No. 20, page 48, were treated as above. Four died before noon on December 26th (two days), four before noon on December 27th, and the remaining three before noon on December 28th (maximum of four days). These parasites were about 1.6 mm. long, and therefore probably in the stage of development shown in Fig. 46.

These experiments are, of course, quite insufficient to give any positive evidence, but in each case the larvae would appear to live much longer than do those of H. muscae and H. microstoma under similar conditions, suggesting a much greater resistance on the part of the H. megastoma embryos than that of the other species.

E. To determine the period of survival of larval H. megastoma in dead flies.

Three flies from Experiment No. 20, page 48, which emerged on the afternoon of December 23rd, were killed in a cyanide of potassium killing-bottle on the morning of December 24th, and placed on moist filter paper in a covered dish. One fly was dissected late in the afternoon, and found to contain two living parasites. The others were examined early on December 26th, when one only was found to be infected, the two parasites which were contained in the abdomen being dead.

4.— Development.

The eggs and young embryos of Habronema megastoma, as found in the uterus of the gravid worm, are illustrated in Fig. 36. The egg (Fig. 36a) measures from 0.04 mm. to 0.05 mm. long by about 0.01 mm. wide, and is similar to that of H. muscae. Later stages in development are shown in Fig. 36b, and c, which measured 0.05 mm. long by 0.013 mm. wide, and 0.053 mm. long by 0.015

mm. wide respectively. Fig. 36d shows the young embryo in a condition sufficiently far advanced to enable it to be definitely distinguished from embryos of H. muscae and H. microstoma by the relative position of the anterior to the posterior end. As will be seen on comparing Fig. 1, of H. muscae, Fig. 18, of H. microstoma, and Fig. 36, of H. megastoma, the tail of the young embryo in the first species never reaches more than half-way along the main part of the body when bent in the egg. In H. microstoma, though a stage comparable with Fig. 1e is not shown, it does occur. In H. megastoma, however, the embryo is seen to be bent in about the middle of its length in several stages. Thus the parasite as it leaves the parent worm, as well as in some subsequent stages (as will be seen later) contrasts in a marked degree with H. muscae and H. microstoma.

In the stage shown in Fig. 36d, the embryo measured 0.056 mm. long by 0.0165 mm. wide.

Still further development is seen in Fig. 36e, which measured 0.056 mm. long by 0.018 mm. wide. Fig. 36f shows an embryo 0.057 mm. long by 0.017 mm. wide in the most advanced stage attained in the uterus of the parent worm. As is the case with the other species dealt with in this report the form of anterior end can be made out only with difficulty. At the anterior end there is evidence of a horn-like process, and a rudimentary pharynx with an adjacent clear space as in H. muscae, but the more or less conspicuous nuclei observed in H. muscae and H. microstoma have not been observed in such young embryos of this species.

Development of the embryo in the tumour.

Further development takes place during the life of the embryo in the purulent matter contained in the stomach tumour. The embryos illustrated in Fig. 37 were found in such circumstances as were others which had ruptured the egg-shell or sheath.

Development of the embryo in faeces.

Doubtless the embryo is carried into the stomach of the horse with the purulent discharge from the several openings in the summit of the tumour, but embryos have not been identified in the stomach or intestines nor in the faeces of naturally infected horses.

The development which probably takes place in the faeces, is illustrated in Fig. 38, a and b. These embryos, taken from an adult worm, were incubated in sterilized faeces for a period of

fifteen days at a temperature of 22°-27° C. (c.f. Experiment No. 19, page 47). The parasite shown in Fig. 38a, which was not enclosed in a sheath, measured about 0.0528 mm. long from the bend in approximately the middle of the body to the anterior end, by about 0.0065 mm. in diameter at its widest part. A large nucleus occurred at about 0.043 mm. from the anterior end, and a smaller one was seen posterior to the first. In some specimens one large nucleus only was seen, and in others there were one or two nuclei as above, and one smaller nucleus at about 0.039 mm. from the posterior end. Other embryos enclosed in sheath or egg-shell were found on the same day and in the same culture. The embryo shown in Fig. 38b measured about 0.104 mm. long from the anterior end to the tip of the tail. The body was bent in the middle in the characteristic manner, and the large nucleus was somewhat further back than usual, i.e., 0.053 mm. from the anterior end. Posterior to what was evidently the rudimentary pharynx there were two clear spaces, which were also observed in the specimens shown in Fig. 36f and Fig. 38a. Posterior to these clear spaces and in the middle line of the anterior fourth of the body was a noticeable aggregation of minute granular bodies, probably the earliest evidence of the developing alimentary system.

Development in the larvae of M. domestica.

Early larval stages of H. megastoma comparable with the stages of H. microstoma illustrated by Figs. 20, 21, 22, and 23, have not been found. The earliest stage known to the writer to occur in the intermediate host is shown in Fig. 39. This parasite was found in a fly larva on December 21st from a culture of sterilized faeces, which was infected on December 3rd, with the contents of a stomach tumour, and then incubated for a period of seven days before being exposed to ingestion by the fly larvae than five days old (c.f. Experiment No. 19, page 47). The parasite was therefore eighteen days old, eleven days of which period may have been passed in the body of the fly larvae. The true period was, however, probably much shorter (see text referring to Fig. 43). The length of the worm was 0.221 mm., and the width near the rectum about 0.046 mm. The base of the oesophagus was 0.099 mm. from the anterior end of the body, and the tip of the tail about 0.042 mm. from the anal operculum.

Two other larvae from the same culture, examined on the same day as the above, were each found to contain one parasite measur-

ing 0.21 mm. and 0.25 mm. long respectively. Both were apparently in the same stage of development.

Had the fly larvae in this culture developed at their usual rate of progress, they should have been well advanced pupae instead of larvae on December 21st. Presumably, therefore, the larval H. megastoma should ordinarily attain the stage of development shown in Fig. 39, whilst its intermediary host is in the pupal stage. Although older and shorter, the larval parasites just referred to were considered to be in a stage of development most comparable with the H. muscae larva shown in Fig. 6.

It is assumed from the examination of a parasite which was found on November 6th in an adult fly from Experiment No. 17, that an intervening moult takes place before the parasite reaches the stage figured in Fig. 40. The larva measured 0.28 mm. long by about 0.04 mm. wide near the rectum, and about 0.038 mm. wide at the base of the oesophagus, which was 0.115 mm. from the anterior end of the body. The moulting cuticle at the anterior end of the body appeared as shown in Fig. 40, which illustrates a larva found in a fly on the same day and from the same culture. Unfortunately the specimen referred to was lost before a drawing and further details could be secured. As will be seen by reference to Experiment No. 17, this parasite was twelve days old. The whole of this period may have been passed within the body of the intermediate host, but this is very improbable, as will be seen in the following paragraph.

The parasite shown in Fig. 40 was found, as already stated, on November 6th in an adult fly from the same culture as the parasites shown in the preceding paragraph; it was therefore twelve days old, and may have passed that length of time in the intermediary host. This larva measured 0.33 mm. long by about 0.038 mm. wide at the base of the oesophagus, which was 0.128 mm. from the anterior end of the body. The pharynx was 0.01 mm. in length, and surrounded at its base by a clear space or vacuole. The oesophagus was 0.012 mm. in diameter at the anterior end, and somewhat larger near the base. Numerous moderately large nuclei were seen in the whole length of the alimentary tract. A group of similar nuclei occurred also at about 0.065 mm. from the anterior end of the body, and elsewhere in the body wall, as shown in Fig. 40. The worm had evidently nearly completed a moult.

The larvae illustrated in Fig. 41 and Fig. 42, also taken from an adult fly, had the same history as the one shown in Fig. 40. The former measured 0.36 mm. long by about 0.040 mm. wide at the

base of the oesophagus, i.e., at 0.12 mm. from the anterior end of the body. Another worm of the same total length and from the same fly measured 0.145 mm. from the anterior end of the body to the base of the oesophagus. The worm shown in Fig. 42 was 0.37 mm. long by about 0.040 mm. wide at the base of the oesophagus, which was 0.14 mm. from the anterior end of the body. In these three worms and most others in a similar stage of development the cuticle at the anterior end was somewhat separated from the body, as seen in Figs. 41 and 42. The nuclei in the alimentary tract were fewer and smaller than those seen in the larva illustrated in Fig. 40, apparently indicating that the latter was hardly so far advanced, since these nuclei are at their maximum almost if not quite as soon as they are first noticeable. Evidently this stage (c.f. Figs. 41 and 42) is comparable with Ransom's Stage 1 of H. muscae and also with the eight-day-old larva (H. muscae) shown in Fig. 8 of this Report, both of which were from fly pupae.

The parasite illustrated in Fig. 43 was evidently in a more advanced stage than the larvae illustrated in Fig. 41 and Fig. 42. It was found on November 8th in a fly from the same culture as the latter, and was, therefore, fourteen days old. The body was 0.5 mm. long by about 0.04 mm. wide at the base of the oesophagus, which was about 0.17 mm. from the anterior end of the body. The pharynx, which was about to moult, was about 0.015 mm. long, and a clear space surrounded it. Nuclei were seen in the body wall and alimentary tract, but they were not made out in that part of the body where, in later stages, the nerve ring is to be found. This stage is near that stage of H. muscae designated by Ransom as Stage 2.

The next stage in development of the larva known to the writer is shown in Fig. 44. The parasite was found on December 20th in an adult fly from the same culture as the parasite shown in Fig. 39, which was found in a fly-larva on December 21st (c.f. p. 52) and also Experiment No. 19, page 47.) The latter (Fig. 39), therefore, may have lived one day longer in the intermediate host than the former (Fig. 44), but as it was considerably less developed it may be assumed that its life in the intermediary was at least several days less than that of the more developed specimen. The larva (Fig. 44) measured 0.87 mm. long by 0.046 mm. wide near the base of the oesophagus. At the base of the pharynx, which was about 0.016 mm. from the anterior end, the body was 0.029 mm. in diameter, increasing to about 0.06 mm. at the base of the oesophagus. The oesophagus measured 0.013 mm. in diameter at

the anterior end, and increased to about 0.02 mm. at its base, which was about 0.247 mm. from the anterior end of the body. The anus was evidently still closed as in early stages. The nerve ring is now clearly distinguishable, being about 0.073 mm. from the anterior end. A few nuclei were seen near the nerve-ring, and in the body wall. The pharynx and posterior end were moulting.

Other larval parasites, including specimens 4-9, of Table 3, were found in flies from the same culture and on the same day. These parasites measured from 0.98 mm. long in Specimen No. 9, to 1.280 mm. long in Specimen No. 4. Possibly all of this series are merely successive steps in the progress of larval development from one definite stage (c.f. Fig. 44) to another (c.f. Fig. 46). All of these most closely resemble the stage of H. microstoma represented by Fig. 14, and therefore Ransom's Stage 3 of H. muscae.

One of the series of larvae referred to above (Specimen No. 7, Table 3) is shown in Fig. 45. In this specimen the cuticle at the anterior end of the body was transversely ribbed and oral lips were seen distinctly. These two features were not observed in less developed specimens. The anus was closed as in earlier stages.

The parasite shown in Fig. 46 (c.f. Table No. 3, Specimen No. 3) is in a markedly more advanced stage of development than any of the preceding ones. Two very definite, and for the purpose of diagnosis very important, characters manifest themselves in the worm, namely:—(1) The oral cavity is distinctly widened anteriorly, thus simulating the characteristic funnel-shaped anterior end of the alimentary canal of the adult, which character alone is sufficient to distinguish this larval stage of H. megastoma from any stage of either H. muscae or H. microstoma (in both of which species the oral cavity is not so widened); (2) a constriction of the body near the anterior end like that so conspicuous in the adult, is distinctly seen beneath the cuticle of the worm.

Whether or not a moult occurs just before these developments become visible is not known. This parasite (Fig. 46) was found on December 26th, encysted in the abdomen of an adult fly, from Experiment No. 20. It will be seen, therefore, that this stage in the development of H. megastoma can only be compared with the corresponding stages in H. muscae (c.f. Ransom's 4th Stage), and in H. microstoma (my Fig. 31) in that this forms an intermediate condition between Stages 3 and 5, recognised as being comparable in other respects in all three species.

The embryo from which it was reared was obtained with many others, from a stomach tumour on December 13th, and on the same

day the culture was offered as food to three-days-old larvae of H. domestica. It was therefore thirteen days old, the whole of which period may have been passed within the body of the intermediary host. The worm was 1.650 mm. long by about 0.033 mm. wide at the base of the pharynx, and 0.053 mm. wide at the base of the oesophagus. The base of the pharynx and oesophagus were about 0.033 mm. and 0.428 mm. respectively from the anterior end of the body. The anal opening, which was 0.069 mm. from the tip of the tail, was still closed as in earlier stages.

The next stage in the development of the larval parasite is illustrated by Fig. 47 (c.f. Table No. 3, Specimen No. 2). The specimen here figured was 1.848 mm. long by 0.082 mm. wide at the base of the oesophagus, ie., at 0.56 mm. from the anterior end of the body. The base of the pharynx and the nerve ring were 0.04 mm. and 0.132 mm. respectively from the anterior end of the body. The anus was still closed, minute spines were evident beneath the cuticle at the tip of the tail, indicating that this stage is comparable with the larval stage of H. microstoma referred to on page 42 of this Report, and with Ransom's 5th stage of H. muscae. This larva was encysted in the abdomen of a fly found on the same day and in the same culture as the parasite in Fig. 46 (c.f. Experiment No. 20, p. 48); it was therefore thirteen days old, and may have lived for the whole of that time in the body of the intermediary fly. It was about to moult.

The final larval stage in the body of the intermediate host is seen in Fig. 48 and Fig. 48A (c.f. Experiment No. 20, page 48). The history of this larva was the same as that of the larva shown in Figs. 46 and 47; it was therefore thirteen days old. As will be seen, the limit of possible age of the larvae in Figs. 46 and 47, and in 48 and 48A is the same, but there is no doubt in my mind, from the internal evidence of the stage of development reached by these two lots of larvae, that those seen in Figs. 46 and 47 were not ingested by the fly larvae so early as was that seen in Figs. 48 and 48A, the latter being now undoubtedly further advanced, and therefore obviously older than the former. It measured 2.244 mm. long by 0.096 mm. wide at the base of the oesophagus, which was 0.63 mm. from the anterior end of the body. The base of the pharynx and the nerve ring were about 0.066 mm. and 0.138 mm. respectively from the anterior end of the body. (For other measurements see Table No. 3, Specimen No. 1). The anus, closed in all earlier stages, was open and the tip of the tail was spinous (c.f. Fig. 48A).

The parasite was in a stage comparable therefore with the larval

H. microstoma shown in Fig. 32, and with that stage of H. muscae designated by Ransom, Stage No. 6.

This final larval stage of H. megastoma found in the body of the adult fly on one occasion only, has also been found frequently, in company with adults, within stomach tumours. Measurements and details of a number of examples of this final stage are given in Table 4.

Thus between the very early stages represented by embryos such as that shown in Fig. 37, and very advanced stages such as shown in Figs. 48 and 48A, both of which were recovered from the interior of tumours, there is a considerable number of stages of development never yet found in the stomach tumours or in the digestive canal of the host, but which form a continuous series of progressive steps, almost entirely (Figs. 39-47) passed in the body of the larva, pupa and imago of Musca domestica, the final stage (Figs. 48 and 48A), being found both in Musca domestica (adult), and in the contents of the stomach tumours of the horse, where they develop into the adult worm.

Summary and Discussion.

It will be seen from an analysis of the experiments carried out to determine the relationship of Musca domestica and Stomoxys calcitrans to the embryo of H. megastoma that Musca domestica exclusively was used in four experiments, and that infection took place in three of these experiments. The failure to infect flies in the fourth experiment cannot be accounted for.

In the positive experiments 35%, 52%, and 15% respectively of the larvae, pupae and adults examined, were infected with from one to sixteen parasites each.

Stomoxys calcitrans exclusively was used in two experiments, in both of which there was no infection.

It was intended to carry out further experiments, viz. :—(1) A culture of embryos of H. microstoma and H. megastoma fed to larvae of both species, and (2) a culture of embryos of all three species of Habronema fed to larvae of both species of fly. Time however did not permit of this being done, nor, chiefly for this same reason, was it found practicable to experiment with other species of Musca.

These experiments show that (1) Musca domestica is an intermediary host of H. megastoma, and (2) all the available evidence is against Stomoxys calcitrans acting, even accidentally, in such

capacity. Thus embryos passed out in the faeces from the horse are taken up by the larvae of Muscae domesctica adults, which have oviposited on the faeces. The faeces remain infective to the fly larvae in this respect up to at least fifteen days after leaving the rectum.

Fly larvae are known to react to infection when three days up to five days old, and possibly earlier and later. After a certain amount of development in the faeces (c.f. Fig. 38) the embryo of Habronema megastoma enters the larva of Musca domestica, then it continues to develop through the fly pupa and adult fly as seen in Figs. 40 to 48, in which condition it is ready to complete its development in the stomach of the horse; where larvae of such a stage have been met with (c.f. Figs. 49 and 49A, and also Table No. 4). H. megastoma has not been found in any of the 182 adult Musca domestica and 63 adult Stomoxys calcitrans caught in the stables during the period May-November, 1917.

In its three last stages in the body of the fly H. megastoma may be differentiated from both H. musca and H. microstoma in corresponding stages of development.

General Summary, Comparison, and Discussion.

Intermediary host.

It has been shown that each of these three species of Habronema found adult in the horse, H. muscae, H. megastoma and H. microstoma require for the completion of their life-cycle that they shall enter the body of a fly; in the case of H. muscae, Musca domestica; in H. megastoma also Musca domestica; and in H. microstoma, Stomoxys calcitrans, or very rarely under experimental conditions, Musca domestica, i.e., H. muscae and H. megastoma find their intermediary host in a non-piercing sucking fly, as distinguished from H. microstoma, which finds its chief host (at least) in a piercing sucking fly. The possible importance of this distinction will be referred to a little later.

It is, of course, quite possible that species of flies other than those experimented with, as herein recorded, are involved in the carriage of these Helminth parasites, but time and availability of material has not so far allowed of experimentation with them. For example, Musca australis, which in the writer's opinion, is likely to be a frequent carrier of Helminth infection, has not been experimented with, "clean" flies not being available at the time the helminth material was at hand. In this connection it is of interest to note

that Johnston (1912, p. 76) has recorded a larval nematode resembling Habronema from Musca vetustissima.

Methods of Infection of Flies.

From the experiments herein detailed, it is obvious, in the case of H. muscae and H. megastoma, since their intermediary host, M. domestica, breeds chiefly in manure heaps that eggs containing embryos or the very early larvae of these two helminths present in the faeces of the infected horse, are taken up during feeding by the larvae of the fly host, in which they continue their development.

In the case of H. microstoma and Stomoxys calcitrans this may seem to be a more difficult matter to understand since Stomoxys calcitrans, by reason of its piercing proboscis is apparently preeminently fitted for the carriage of those parasites which pass some stage in the blood-stream of the host whence the adult fly derives its food supply. We have no reason, however, to suppose either that Habronema larvae ever occur in the blood-stream, or if they do, that this would form their normal method of transmission. It is evident on the other hand, that since Stomoxys does breed at times in stable manure, the circumstances are propitious for the ingestion of the embryo-containing eggs or young larvae of H. microstoma from infected faeces by the larvae of Stomoxys calcitrans, as has herein been shown to occur, and that to a marked extent.

It has been shown during these investigations that faeces infected with the embryos of H. microstoma and H. megastoma remain infective to the larvae of Stomoxys calcitrans and Musca domestica respectively for periods up to fifteen days in each species and in the case of H. muscae, the embryos have been shown to be infective to larvae of Musca domestica for periods up to eight days, i.e., the largest period tested. It has been shown further that the larvae of both species of fly react to infection when from two days to nine days old.

No evidence is forthcoming to show that the helminth larvae can enter the fly-larvae by penetration or in any way other than by ingestion.

Development within the Flies.

Commencing from the earliest larval stage of each of the Helminths under discussion, found in the larvae of the respective fly-hosts, it has been found that the "six stages" shown by Ransom, and confirmed by my own experiments to occur in the life of H.

muscae within the intermediary, also occur in a closely similar manner in H. megastoma and in H. microstoma.

It is worth recalling here that I have been able to show that several steps in the development of H. muscae occur in the fly-larvae and pupae of Musca domestica before the stage in the fly-pupae which Ransom has designated Stage 1, but for the convenience of other workers, I have adhered to the designations adopted by Ransom, in spite of the criticisms made by Seurat.

In each case, the "fifth stage" is that in which the spinous character of the tip of the tail is first seen, viz. :—beneath the cuticle, the anal operculum being still present, and the anus closed. The "sixth stage" is characterised by the further development of the spinous tip of the tail, by the disappearance of the anal operculum and the opening of the anus.

In the preceding text it has been stated that it is possible to differentiate between H. megastoma on the one hand and H. muscae and H. microstoma on the other in the later larval stages reached in the body of the fly, for the characteristic appearance of the head of the adult H. megastoma can be detected in the fourth larval stage of this worm as found in the adult Musca domestica. Further, comparative measurements have been given to support the conclusion that it is possible also to differentiate between larval H. muscae and H. microstoma in at least the sixth or final stage. In view of the importance attached to the correct specific diagnosis of the parasites found in, and supposed to be the causative agents of, the lesions known here as "Habronemic conjunctivitis," and "Habronemic granulomata," and also to enable others to more correctly identify larvae belonging to any one of these three species found in caught flies of the same and other host species, it appears desirable to discuss further one aspect of the evidence on which the writer has based his statements and conclusions, namely, the evidence contained in Tables 1, 2, 3, and 4 of this Report. For this purpose the length of the body and the distance of the pharynx, nerve-ring and oesophagus respectively from the anterior end of the body will be considered. In Table I (H. muscae from "clean" adult Musca domestica), Specimens 1-6, all of which are in the sixth or final stage attained in the body of the fly, show the length of the body to be from 2.310 mm.-2.541 mm., an average length of 2.398 mm. The length of the oesophagus is from 0.83 mm.-0.97 mm., or an average length of 0.898 mm. The distance of the nerve-ring from the anterior end of the body is from 0.132 mm.-0.14 mm., an

average distance of 0.1353 mm.; the length of the pharynx is from 0.046 mm.-0.049 mm., or an average of 0.047 mm.

In Table 2 (H. microstoma from "clean" adult Stomoxys calcitrans), Specimens 1-6, all of which are in the same relative stage of development as the above, show the body to be 1.600 mm.-1.815 mm. long, the average being 1.731. The length of the oesophagus is 0.65 mm.-0.792 mm., or an average length of 0.7403 mm. The distance of the nerve-ring from the anterior end of the body is 0.105 mm. to 0.132 mm. long, or an average distance of 0.1194 mm. (in five specimens only). The length of the pharynx is 0.046 mm.-0.053 mm., or an average length of 0.0505 mm.

Table 3 (H. megastoma from "clean" adult Musca domestica) includes only one specimen in a stage comparable with the above, i.e., the sixth stage. This worm (Specimen No. 1) measured 2.805 mm. long. The oesophagus, nerve-ring and base of the pharynx were distant respectively 0.63 mm., 0.138 mm., and 0.066 mm. from the anterior end of the body.

In Table 4 (H. megastoma from tumours), Specimens 1-6, all of which are in the same stage of development as Specimen 1 in Table 3, show the length of the body to be 2.310 mm.-2.805 mm. long, or an average length of 2.678 mm. The length of the oesophagus is 0.58 mm.-0.75 mm., or an average length of 0.685 mm. The distance of the nerve-ring from the anterior end of the body is 0.148 mm.-0.181 mm., or an average distance of 0.164 mm. The pharynx varied in length from 0.079 mm.-0.089 mm. the average length being 0.083 mm.

The following tabulated statement shows the average length of the body and parts referred to of the above six specimens each of H. muscae, H. microstoma (from "clean" adult flies), and H. megastoma (from tumours) and of one H. megastoma from a "clean" adult fly. Unfortunately only one H. megastoma from a fly was available for measurement.

	H. muscae Average of 6 "6th stage," larvae from adult M. domestica flies. mm.	H microstoma Average of 6 "6th stage" larvae from adult Stomoxys flies. mm.	H. megastoma One "6th stage" larva from an adult M domestica fly. mm.	H. megastoma Average of 6 "6th stage" larvae from a stomach tumour. mm.
Length of body	2.398	1.731	2.244	2.678
Oesophagus, base from anterior end of body	.898	.740	.630	.685
Nerve Ring	.135	.119	.138	.164
Pharynx	.047	.050	.066	.083

Neither the excretory opening and its main tube, nor any indication of the developing genital organs has been seen in any of the larvae herein described.

Bull (MSS. 1918), who records having reared H. megastoma from the embryonic stage to the "sixth stage," in Musca domestica, considers that in the final larval stage reached in the body of the fly H. megastoma cannot be differentiated from larval H. muscae in the same relative stage of development. The evidence I have adduced does not support this conclusion. This investigator used a culture of H. megastoma (from a tumour) in non-sterilized faeces from a horse which was apparently not subsequently post-mortemed to determine the presence or absence of H. megastoma in the stomach. Previously, however, he bred flies from larvae fed on faeces from the horse, and finding them all negative for Habronema he assumed that the horse did not contain Habronema embryos. Some of my experiments, notably Experiment No. 18, page 47, show that flies may be reared from faeces known to be infected and yet, on examination, prove to be negative for Habronema. The possibility that Bull was dealing with H. muscae and not H. megastoma is therefore not excluded.

As to the path taken by these Helminth larvae within the fly from the time the larvae are ingested by the fly-larvae, the evidence is not as complete as could be desired. I can say, however, that with regard to H. muscae and H. microstoma, the youngest larvae of these species, found in the larvae of Musca domestica in the former case, and in larvae of Stomoxys calcitrans in the latter, occur in the alimentary canal.

The next succeeding stages in each case are found either free in the body cavity or encysted in the fat-body of the larvae. No young stages of H. megastoma corresponding to the above are yet known in the larvae of M. domestica. In the pupa the helminth larvae are still found free or encysted in the broken-down tissues.

The exact position taken up by the developing parasitic larvae in the tissues of the pupa and early imago have not yet been determined. In flies that have emerged from the pupal case, the parasites in the case of H. muscae and H. microstoma have been found free in the body cavity of the abdomen, thorax, and head of the fly-host, and also encysted in the tissues surrounding the alimentary canal and on the surface of the tracheae. This is also true of H. megastoma, except that the solitary example of the "6th stage" of this parasite found in the fly host (M. domestica) was free.

It is interesting to note that in Musca domestica, even when very heavily infected with H. muscae, I have never been able to find any larvae in the proboscis proper, i.e., not further forward than the rostrum. On the other hand, as already stated, the proboscis of Stomoxys calcitrans most frequently harbours the "Sixth Stage" larvae of H. microstoma.

Whether there is any tendency for the larvae to gravitate towards the head of the fly-host I cannot positively say, except that in the case of M. domestica the majority are usually in the abdomen, whereas in Stomxys at least half the total parasites found are in the head.

Method of Infection of the Horse.

In view of the present knowledge the two obvious possibilities are (1) ingestion of the infected fly, or of free larvae which have escaped from the fly-host into the food or drink of the horse, or of larvae which have escaped from the fly-host on the lips or spot accessible to the lips or tongue of the horse, and (2) by penetration of, or inoculation into, the skin of the horse.

It is somewhat curious that in all these experiments I have never once come across any flies in the stomach of the horse, although I have no doubt that they are ingested and so reach the stomach. I have therefore no positive evidence as to whether the larva of the worm is passively liberated by the digestion of the fly, or whether it escapes prior to such digestion. I am strongly inclined, however, to think that the former is the case.

As to the possible infection of the horse by way of the skin, the evidence is quite insufficient. It has been shown very clearly (Figs. 34 and 35) that the "sixth stage" or final larval stage of H. microstoma finds its way very freely into the piercing proboscis of the adult Stomoxys calcitrans, but whether under any circumstances this "sixth stage" larva of H. microstoma can be transmitted to the skin or blood-stream of the equine host is not known—the only experiments to this end so far attempted by the writer having failed apparently from too heavy infection of the fly-host, so choking the proboscis.

As shown by Descazeaux, Rivolta and others (Railliet's Report, 1915), and by Bull (1916), and Lewis and Seddon (in press) in Australia, the larvae of some member of the Superfamily Spiruroidea (characterised by the presence of a spinous tipped tail) are undoubtedly associated with the formation of lesions in the skin known as "Cutaneous habronemiasis," and "Habronemic conjunc-

tivitis," these larvae being regarded by Raillict and Bull as the larvae of an equine species of Habronema. The present writer cannot, however, from the material and evidence so far at his disposal definitely refer the larvae so far seen to anyone of the three species of Habronema, the development of which is herein described. It was at first thought when it was found that Stomoxys calcitrans was the chief intermediary host of H. microstoma, that Bull (1916) was right in so far as he believed these larvae found by him in such lesions were introduced by a biting insect and that really they were the larvae of H. microstoma. I am indebted to Lewis and Seddon for allowing me to examine their material, and in the only specimen in which the anterior end is in a sufficiently good condition for this purpose (their Specimen No. 3), the pharynx of the larva in the lesion is undoubtedly not that of H. muscae, nor apparently that of H. microstoma. It is just possible that it is that of a H. megastoma larva, but the other characteristic features of the head of a larva of H. megastoma of this stage of development are entirely wanting. So that, as stated above, I cannot regard it as in any way proved that the examples of "Habronemic conjunctivitis" under my notice have been caused by any of the three equine Habronema species.

Development into adult in Horse.

Once freed from the fly-host in the stomach of the final host, the "sixth stage" larva develops into the adult in the stomach contents in the case of H. muscae and H. microstoma; these are possibly kept from being carried away in the ingesta by inserting their heads into the mucous membrane, or at least into the lumen of the glands.

In the case of H. megastoma, the larva either finds its way into a nodule already formed (since, as already stated, the final larval stage has been frequently found with adults in fully formed tumours or nodules), or else penetrates the lumen of glands, there setting up the irritation which results in the formation of a new tumour. What determines which of the two shall occur I cannot say.

Development of next generation in stomach and intestine of final host and its faeces.

As already seen, the eggs containing embryos must be poured out in considerable numbers into the interior of the nodule in the case of H. megastoma, and thence into the cavity of the stomach,

and in H. muscae and H. microstoma directly into the stomach. As seen by comparing Figs. 1d and 4 of H. muscae and Figs. 18d and 20 of H. microstoma, the former in each case being that of embryos still within the egg-shell as extruded from the female and present in the stomach contents, the latter being the first stage obtained from a larva in each case, very little development goes on after emergence from the egg-shell, either in the stomach or intestines, or in the faeces, i.e., until the helminth larva enters its new intermediary host. In the case of H. megastoma the young embryo enclosed within the egg shell is seen in Fig. 36f, but unfortunately a young larva comparable with Fig. 4 of H. muscae and with Fig. 20 of H. microstoma has not been found in the case of H. megastoma.

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DESCRIPTION OF PLATES.

Plate II.—Habronema muscae.

Fig. 1.—Egg and embryos from female.
Fig. 2.—Embryos from faeces of horse.
Fig. 3.—Embryo after six days' incubation in faeces.
Fig. 4.—Embyro from a Musca domestica larva.
Figs. 5-12 (inclusive).—Larvae from Muscae domestica pupae.
Fig. 13.—Larva (anterior end) from a Musca domestica pupa.

Plate III.—H. muscae.

Fig. 13a.—The above (posterior end).
Fig 14.—Larva (anterior end) from Musca domestica fly.
Fig. 15.—Larva (anterior end), from Musca domestica fly.
Fig. 16.—The above (posterior end).
Fig. 17.—Proboscis of House Fly (Musca domestica), showing two larvae of Habronema muscae.

All Figures, excepting 17, outlined by camera lucida.

Figures 1-9 and 11-13a inclusive from life.

Figures 10, 14, 15 and 16 from specimens fixed in alcohol and mounted in glycerine jelly.

Fig. 17, Photomicrograph.

Plate IV.—H. microstoma.

Fig. 18.—Egg and embryos from female.
Fig. 19.—Embryo after five days' incubation in faeces.
Fig. 20.—Embryo from a Stomoxys calcitrans larva.
Figs. 21-23 (inclusive).—Larvae from Stomoxys calcitrans pupae.
Fig. 24.—Larva from Stomoxys calcitrans pupa.
Fig. 25.—The above in reduced scale.
Fig. 26.—Larva from a Musca domestica fly.

PLATE V.—H. MICROSTOMA.

Fig. 27.—Larva from a Stomoxys calcitrans pupa.
Fig. 28.—The above (posterior end).
Figs. 29 and 30.—Larvae from a Stomoxys calcitrans pupa.
Fig. 31.—Larva from a Stomoxys calcitrans fly.
Fig. 32.—Larva from Stomoxys calcitrans fly.
Fig. 33.—The above (posterior end).

PLATE VI.

Figs. 34 and 35.—Proboscis of Stomoxys calcitrans fly showing larval Habronema microstoma.

All figures, excepting 34 and 35, outlined with camera lucida.

Figs. 34 and 35, Photomicrographs of specimens fixed in alcohol and mounted in glycerine jelly.

Fig. 18, from specimens fixed in lacto-phenol.

Figs. 19-30, inclusive, from life.

Figs. 31-33, inclusive, from specimens fixed in alcohol and mounted in glycerine jelly.

PLATE VII.—H. MEGASTOMA.

Fig. 36.—Egg and embryos from female.
Fig. 37.—Embryos from stomach tumour.
Fig. 38. Embryos from a tumour after fifteen days' incubation in faeces.
Fig. 39.—Larva from a Musca domestica larva.
Figs. 40 to 45.—Larvae from Musca domestica flies.

PLATE VIII.

Figs. 46, 47. Larvae from Musca domestica flies.
Fig. 48.—Larva from a Musca domestica fly.
Fig. 48a.—The above (posterior end).
Fig. 49.—Larva from a stomach tumour.
Fig. 49a.—The above (posterior end).

All figures outlined with camera lucida.

Figs. 36-39 and 41-43 inclusive from life.

Figs. 40 and 44-49a inclusive from specimens fixed in alcohol and mounted in glycerine jelly.

TABLE I.

HABRONEMA MUSCAE FROM MUSCA DOMESTICA FLIES (ADULTS).

	1	2	3	4	5	6	7	8	9	10	11	12
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	2.541	2.475	2.376	2.376	2.310	2.310	2.079	2.013	1.848	1.485	1.435	.800
Diameter, about .040 mm. from anterior end	.040	.040	.039	.039	.029	.033	.033	.033	?	?	.029	.033
Diameter, at anal opening	.036	.033	?.026	?	.029	.026	?	?	?	.030	?.026	?
Diameter, maximum (at end of oesophagus)	.056	.066	.050	.049	?	.052	.066	.056	.050	?	.043	?
Oesophagus, base from oral opening	.970	.910	.900	.920	.830	.860	.740	.775	.640	.460	.430	.300
Oesophagus, least diameter (at anterior end)	.010	.013	.013	?	.016	.016	.016	?.010	.013	.013	.013	?
Oesphagus, greatest diameter (at base)	.049	.049	.036	.039	.033	.033	.036	.030	.023	?	.020	?
Anal opening from tip of tail	.082	?	.089	?	.089	.089	.089	?	.079	.053	.050	?
Nerve ring from anterior end	?.135	.140	.132	.132	?.135	.138	.122	.122	.120	.092	.102	.100
Pharynx, length of	.046	.046	.046	.049	.046	.049	.043	.043	.043	.030	.030	.020
Tip of tail	spinous	spinous	spinous	spinous	spinous	spinous	spines under cuticle	spines under cuticle	not spined	not spined	not spined	not spined
Anal operculum	absent	absent	absent	absent	absent	absent	present	present	present	present	present	present

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken. Specimens 7, 8, 9 and 10 were in a moulting condition.

TABLE II.

HABRONEMA MICROSTOMA FROM STOMOXYS CALCITRANS (ADULTS AND PUPAE).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length - - - - - - -	1.815	1.800	1.740	1.716	1.716	1.600	1.586	1.584	1.584	1.584	1.584	1.570	1.485	0.950
Diameter, about .040mm. from anterior end -	?	.033	?	?	.030	.030	.030	.030	?	?	?	.030	?	.020
Diameter, at anal opening - - -	?	?	?	?	.039	.030	.036	.030	.030	.030	.030	?	.033	.030
Diameter, maximum (at end of oesophagus) -	.046	.072	.066	?	.063	.049	.046	.053	.049	.043	.049	.049	.049	.039
Oesophagus, base from oral opening - -	.750	.770	.740	.792	.740	.650	.680	?.680	.670	.680	.670	.640	?.700	.380
Oesophagus, least diameter (at anterior end) -	.013	?	.013	.013	.013	.010	.020	.010	.010	.013	.013	?	.013	.010
Oesophagus, greatest diameter (at base) -	.026	?	?	.036	.029	.026	.026	.033	.026	.030	.030	.030	.030	.016
Anal opening from tip of tail - - -	?	.086	.066	?.082	.076	.066	.069	.066	.075	.056	.066	?	.059	.043
Nerve ring from anterior end - - -.	.120	?	?.132	.130	.110	.105	.102	?	.100	.102	.105	.108	.100	.092
Pharynx, length of - - - -	.053	.053	.049	.049	.053	.046	.043	.046	.046	.043	.046	.046	.049	.030
Tip of tail - - - - - -	spinous	spinous	spinous	spinous	spinous	spinous	?spines under cuticle	spinous	spinous	spinous	spinous	spinous	spines under cuticle	not spined
Anal operculum - - - - -	absent	absent	absent	absent	absent	absent	present	absent	absent	absent	absent	absent	present	present

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.

Specimens 7, 13 and 14 were in a moulting condition.

Specimens 7 and 13 were found in well-developed pupae: the remainder were from adults.

Six other larvae (from pupae) measuring from 1.419 mm. to 1.551 mm. were in similar condition to specimens 7 and 13.

TABLE III.

HABRONEMA MEGASTOMA FROM MUSCA DOMESTICA FLIES (ADULTS).

	1	2	3	4	5	6	7	8	9	10
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	2.244	1.848	1.650	1.280	1.221	1.188	1.080	0.990	0.980	0.870
Diameter, about .040 mm. from anterior end	.049	.033	.035	.030	.029	.026	.029	.026	?	.029
Diameter, at anal opening	?.049	.039	.039	.036	.036	.039	.036	?	?	?
Diameter, maximum (at end of oesophagus)	.096	.082	.053	.043	.049	.046	.043	.046	?.053	.046
Oesophagus, base from oral opening	.630	.560	?.428	.330	?.340	.330	.290	.260	? 303	?.247
Oesophagus, least diameter (at anterior end)	.020	.016	.020	.013	?.010	.016	.013	.013	.010	.013
Oesophagus, greatest diameter (at base)	.049	.036	.023	.020	?	.023	.020	?	.016	.020
Anal opening from tip of tail	?	?.073	.069	.056	?	.063	.063	.066	?	?
Nerve ring from anterior end	.138	.132	.120	.099	.099	.109	.099	.099	.099	.073
Pharynx, length of	.066	.040	.033	.036	.030	.033	.030	.026	.026	.016
Tip of tail	spinous	spines under cuticle	not spined	not spined	not spined	not spined	not spined	not spined	not spined	not spined
Anal operculum	absent	present	present	present	present	present	present	present	present	present

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.
Specimens 2 and 8 were in a moulting condition.
Specimen 2 was found in a cyst.

TABLE IV.

LARVAL HABRONEMA MEGASTOMA FROM STOMACH TUMOURS.

	1	2	3	4	5	6
	mm	mm.	mm.	mm.	mm.	mm.
Length	2.805	2 805	2.772	2.739	2.640	2.310
Diameter, at about .040 mm. from anterior end	.049	.052	.049	.013	.049	.049
Diameter, at anal opening	.049	.056	.046	?	.049	?
Diameter, maximum (at end of oesophagus)	.115	.099	.118	.089	.099	.122
Oesophagus, base from oral opening	.750	.700	.750	.680	.650	.580
Oesophagus, least diameter (at anterior end)	.022	.016	.020	.019	.022	.022
Oesophagus, greatest diameter (at base)	.049	.059	.050	.046	.056	.059
Anal opening from tip of tail	.105	?.118	.105	?	.118	?
Nerve ring from anterior end	.181	.165	.165	.165	.165	.148
Pharynx, length of	.082	.082	.082	.085	.089	.079
Tip of tail	spinous	spinous	spinous	spinous	spinous	spinous
Anal operculum	absent	absent	absent	absent	absent	absent

The above specimens were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.

TABLE V.

HABRONEMA SP. FROM MUSCA DOMESTICA FLIES (ADULTS) EXPOSED TO MIXED INFECTION OF H. MUSCAE AND H. MICROSTOMA.

	1	2	3	4	5	6
	mm.	mm.	mm.	mm.	mm.	mm.
Length	2.145	2.178	1.586	1.500	1.386	1.353
Diameter, about .040 mm. from anterior end	—	—	—	—	—	—
Diameter, at anal opening	.033	?	.033	.043	.033	?
Diameter, maximum (at end of oesophagus)	.063	.053	.053	.069	.049	.059
Oesophagus, base from oral opening	.820	.800	.560	.550	.540	.500
Oesophagus, least diameter (at anterior end)	.013	?	.016	.016	.013	?
Oesophagus, greatest diameter (at base)	.033	.026	.030	.026	.026	.030
Anal opening from tip of tail	.099	?	.073	.063	?	?
Nerve ring from anterior end	.148	.132	.112	.108	.099	.102
Pharynx, length of	.049	.049	.020	.031	.026	.026
Tip of tail	spinous	spinous	?	?	not spined	not spined
Anal operculum	absent	absent	present	present	present	present

Specimens 1 and 2 probably H. muscae.
Specimens 3, 4, 5 and 6 probably H. microstoma.
The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.
Specimens 3-6 inclusive were in a moulting condition.

TABLE VI.

HABRONEMA MICROSTOMA (?) FROM STOMOXYS CALCITRANS (ADULTS) FROM MIXED INFECTION OF H. MUSCAE AND H. MICROSTOMA.

	1	2	3	4	5	6	7	8	9	10	11
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	1.815	1.650	1.650	1.620	1.430	1.320	1.221	1.188	1.150	1.130	1.100
Diameter, at anal opening	.030	.033	.030	.033	?	?.043	.033	.036	.036	.033	.033
Diameter, maximum (at end of oesophagus)	.043	.0 6	.039	.043	.043	.043	?	.046	.049	.043	.050
Oesophagus, base from oral opening	.690	.730	?	.720	.660	.600	.530	.485	.430	.400	.370
Oesophagus, least diameter	.010	?	.013	?	.013	.013	.013	.013	.013	.013	.013
Oesophagus, greatest diameter	.023	.026	.023	.023	.023	.023	.026	.023	.026	.026	.026
Anal opening from tip of tail	.076	.073	.069	.069	?	?	.053	.053	.053	.046	.049
Nerve ring from anterior end	.109	.120	.115	.112	.115	.115	.105	.112	.112	.112	.109
Pharynx, length of	.049	.049	.049	.046	.046	.019	.046	.046	.030	.026	.023
Tip of tail	spinous	?	spinous	spinous	not spined	not spined	not spined	not spined	not spined	not spined	not spined
Anal operculum	absent	absent	absent	absent	?	?	present	present	present	present	present

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.

Specimens 2, 3, 5, 6, 7, 8, 9, 10 and 11 were in a moulting condition.

TABLE VII.

HABRONEMA MUSCAE (?) FROM MUSCA DOMESTICA FLIES (ADULTS) EXPOSED TO A MIXED INFECTION OF H. MUSCAE AND H. MICROSTOMA. (Cf. Table VIII.)

	1	2	3	4
	mm.	mm.	mm.	mm.
Length	2 277	2.277	2.244	2.178
Diameter, at anal opening	—	—	—	—
Diameter, maximum (at end of oesophagus)	.049	.049	.053	.049
Oesophagus, base from oral opening	.800	.770	.770	.800
Oesophagus, least diameter	.013	.015	—	.013
Oesophagus, greatest diameter	.030	.030	.031	0 28
Anal opening from tip of tail	—	.086	?.082	?.082
Nerve ring from anterior end	.115	.115	.122	.119
Pharynx, length of	.043	.043	.040	.043
Tip of tail	spinous	spinous	spinous	spinous
Anal operculum	absent	absent	absent	absent

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.

TABLE VIII.

HABRONEMA MICROSTOMA (?) FROM STOMOXYS CALCITRANS FLIES (ADULTS) EXPOSED TO A MIXED INFECTION OF H. MUSCAE AND H. MICROSTOMA. (Cf. Table VII.)

	1	2	3	4	5	6
	mm.	mm.	mm.	mm.	mm.	mm.
Length	1.716	1.683	1.650	1.617	?1.584	1.584
Diameter, at anal opening	.030	.033	.030	.033	.030	.030
Diameter, maximum (at end of oesophagus)	.049	.049	.049	.049	.049	.053
Oesophagus, base from oral opening	.690	.710	.700	.660	.720	.650
Oesophagus, least diameter	013	.010	.013	.013	.010	.010
Oesophagus, greatest diameter	.030	.026	.023	.026	.020	.027
Anal opening from tip of tail	.076	.076	.073	.076	.079	.073
Nerve ring from anterior end	.112	.105	.109	.099	.105	.102
Pharynx, length of	.046	.049	.049	.046	.049	.046
Tip of tail	spinous	spinous	spinous	spinous	spinous	spinous
Anal operculum	absent	absent	absent	absent	absent	absent

The above larvae were fixed in 70% alcohol and mounted in glycerine jelly before measurements were taken.

TABLE IX.

CENSUS OF NEMATODE PARASITES FOUND IN 39 HORSES' STOMACHS.

Horse.	Date.	H. muscae.	H. microstoma.	H. megastoma.
1	22/5/17	Absent	Absent	Present
2	31/5/17	P.	A.	P.
3	3/7/17	A.	A.	P.
4	9/7/17	P.	A.	P.
5	18/7/17	P.	A.	P.
6	10/8/17	A.	A.	P.
7	13/8/17	P.	A.	P.
8	16/8/17	P.	A.	A.
9	24/8/17	P.	A.	A.
10	29/8/17	P.	A.	A.
11	29/8/17	A.	A.	P.
12	3/9/17	P.	P.	P.
13	5/9/17	A.	A.	A.
14	6/9/17	P.	P.	A.
15	10/9/17	P.	A.	A.
16	1/10/17	P.	A.	A.
17	3/10/17	P.	A.	P.
18	8/10/17	P.	P.	P.
19	10/10/17	P.	P.	A.
20	22/10/17	P.	P.	A.
21	25/10/17	P.	P.	P.
22	29/10/17	P.	A.	A.
23	21/11/17	P.	A.	A.
24	26/11/17	P.	P.	P.
25	28/11/17	P.	P.	P.
26	3/12/17	P.	P.	P.
27	7/12/17	P.	A.	A.
28	13/12/17	P.	P.	P.
29	18/12/17	P.	A.	P.
30	21/12/17	P.	P.	A.
31	9/1/18	P.	A.	A.
32	11/1/18	P.	A.	A.
33	14/1/18	P.	P.	A.
34	18/1/18	P.	P.	P.
35	21/1/18	P.	P.	A.
36	23/1/18	P.	A.	P.
37	1/3/18	A.	A.	A.
38	5/3/18	P.	A.	A.
39	7/3/18	P.	A.	A.

PART II.

Certain points in the Life-History of Melophagus ovinus, Linn., the Sheep Louse-fly, or "Sheep-Tick."

Introduction.

The life-history and habits of the Sheep Louse-fly, or "Sheep-Tick" (Melophagus ovinus Linn.) have been known for many years as a result of investigations carried out in Europe and U.S.A. Prior to 1916 there do not appear to have been any similar investigations carried out here, and as there was no known marked difference in Australia from the life-history of the pest as known elsewhere, legislation for the control of the Sheep Louse-fly by dipping was introduced accordingly. The enforcement of the Sheep Dipping Act, however, has not had the effect of eradicating the pest. Many sheep-owners contend that this failure is due to the fact that the Louse-flies and their pupae become dislodged from the fleece of the host and remain viable in the grass, brushwood, or elsewhere, for a longer or shorter period, during which the pupae develop into young Louse-flies, which, with similarly dislodged adults, subsequently infect "Tick"-free sheep.

In view of the importance of this contention it seemed desirable that the points in question as well as others in the life-history and habits of this pest should be investigated. With this object in view, certain experiments were begun by Sweet and Seddon in this Institute in the summer of 1916, but though they showed some difference from observations elsewhere they were still incomplete, and required confirmation and extension. The present writer therefore commenced a series of observations and experiments in May, 1917, to verify under a variety of conditions, the work of Swingle in U.S.A. and Sweet and Seddon in Victoria, and also to determine the period of viability of the pupa when removed from the host. The chief subjects upon which further information was sought were :—

(1) Incubation period of the pupa on the host.
(2) The period required by the young Louse-fly to reach maturity —i.e, the period elapsing between its emergence from the parent and the extrusion of the first offspring.
(3) The length of life of the female fly.
(4) The number of pupae extruded by an individual female and the time elapsing between each extrusion.

(5) The period of viability of the insect when removed from the host, (a) when under one day old and unfed, (b) when between three and seven days old, and (c) in the adult condition.

(6) The period of viability of the pupa when removed from the host and kept under varying conditions.

Historical.

The sheep Louse-fly is one of the best known external parasites of the sheep, and has long been known in Europe and America as a pest of some considerable importance. The life history and habits of the fly are referred to briefly and more or less vaguely in many text-books and other publications. In many of these the writers express widely different views upon such important details as the length of life of the female Louse-fly, the number of pupae extruded by the female and the intervals between each extrusion. Dr. Cooper Curtice (1890), however, gives a more detailed account of the habits of the parasite, and some of his observations will be referred to later on in this Report.

The records of investigations and observations by Dr. L. D. Swingle (1913) are the most complete so far published. This investigator, after some initial failures, was able to obtain precise information on many points in the life-history of the parasite, which appear to have been merely conjectured hitherto. He showed that the period which elapsed between the deposition of the pupa, or more correctly the larva, to the emergence of the young Louse-fly was 19-23 days in summer, and 19 to 36 days in winter. Young males and females, he found, are capable of copulating within three or four days after their emergence, and the female reaches maturity, i.e., extrudes the first pupa, fourteen to thirty days after its emergence from the puparium. There is great mortality among the young "ticks" before they take their first meal, but he was able to keep female "ticks" under observation for five and a-half months, and considered that some of them probably live much longer, although many die earlier.

The rate of pupa laying, counting from the deposition of the first one, was found to be one pupa every seven or eight days. The number of pupae laid by an individual female depends upon the length of her life. For a female living four months, which he considered might be regarded as an average life-time, the number is about ten to twelve pupae. For one living six months the number is fifteen or more.

Professor W. B. Herms refers briefly to the Louse-fly, remarking that when off the sheep the insects die in from two to eight days.

The investigations made by Dr. Georgina Sweet and Mr. H. R. Sedden, B.V.Sc. (1917) dealt with one aspect of the subject, namely, the viability of the sheep Louse-fly when removed from the host. These authors refer to the statements of earlier investigators and authors as showing that the life of the parasite off the host and deprived of its food is generally believed to be from two to seven days. They were unable to find any record of sheep Louse-flies being kept alive under these conditions to the eighth day. Their own investigations, which are recorded in detail, showed that under certain conditions the Louse-fly lived for varying periods up to eleven and three-quarter days off the host and without food. The condition found to be most favourable was the moderately cool, uniform temperature of a cellar. Two groups of insects were kept under such conditions, one group on bare soil and the other on soil on which rested a few dry leaves. The first group were all dead in eleven days, whilst the second group were all dead in eleven and three-quarter days. At the same time another group was kept on wool in the cellar; these were all dead in four days. In one experiment in early December (summer), a group of Louse-flies was placed on a moist sod of lawn grass out of doors; these were all dead in five and three-quarter days. In two other experiments out of doors, all the insects died in two and three-quarter days.

1. Experiments to determine the incubation period of the pupae.

Experiment No. 1.

Eleven pupae extruded during the preceding twelve hours were placed (May 30th) in a small muslin bag secured to the fleece on a sheep's back, $\frac{1}{4}$ in. to $\frac{1}{2}$ in. from the skin and $2\frac{3}{4}$ in. to 3 in. from the surface of the wool, the sheep being housed in a brick stall, in which the temperature ranged during the experiment from 45°F. to 47°F. Two young Louse-flies emerged on the twenty-second day, three on the twenty-third day, and three on the 24th day. Three pupae failed to produce young.

Experiment No. 2.

Twelve pupae extruded between 2 p.m. on September 10th and 5 p.m. on September 11th (early spring), by females enclosed within a small area of wool on a sheep's back, produced four young flies on

the nineteenth day, five on the twentieth day, and two on the twenty-first day. The remaining pupa was infertile. The area of wool, 2 in. in diameter, was enclosed in a metal ring 3 in. in diameter and 1 in. deep, secured to the skin with pitch plaster. The wool was ¾ in. long and the pupae were laid by the females about the middle of the staple. The stall used was the one referred to above, and in it the temperature ranged from 47°F. to 72°F. during the experiment.

Summary and Observations.

The incubation period of the pupa on the host has been found to be twenty-two to twenty-four days during the winter months, May and June, when the temperature varied between 43°F. and 47°F. and nineteen to twenty-one days during the spring months, September and October, when the temperature ranged from 47°F. to 72°F.

Swingle found in U.S.A. that the incubation period of the pupa on a sheep kept in a barn was twenty to thirty-six days in winter, when the average minimum temperature was 7.2°F. and the average maximum temperature 27.3°F. In summer, when the average minimum temperature was 44°F. and the average maximum temperature 74°F., the period was nineteen to twenty-three days. He considered that were the sheep turned out of doors in winter, the period might be increased to forty or forty-five days in some cases.

2. To determine the period required by the young Louse-fly to reach maturity, i.e., the period elapsing between its emergence and the extrusion of the first pupa.

Experiment No. 3.

On May 21st one male and eight female "ticks" which emerged from their pupae on the previous day were placed in a small area of wool on a sheep's back. The temperature in the sheep-pen, which was similar to the one referred to on page 79, ranged from 44°F. to 66°F. during the experiment. The wool was about ¾ in. long and the enclosed space about 2½ in. in diameter. The surrounding wool was closely shorn to allow a clear space of six inches around the 2½ in. circle of standing wool. Vaseline was then smeared freely on the shorn portion with the object of preventing the young "ticks" escaping. On the following day (May 22nd), several adult "ticks" from other parts of the host were found in the area under-

observation. These were destroyed, and six young male "ticks" of unknown ages were liberated with the nine young "ticks" in the enclosure. To prevent the escape of the fifteen "ticks," a piece of muslin was placed over them and the edges fastened down to the skin with liquid glue. The glue did not hold very securely, and it was found necessary to renew the muslin daily. On May 26th three of the young "ticks"—the only surviving females—were mating. On May 30th young larvae were evidently present in the abdomen of all three. On June 4th three pupae were found attached to the wool about ½ in. from the skin. One of these pupae had been extruded very recently, as shown by its pale colour. The muslin cover was then removed, and a collar or cup of buckram 1½ in. deep by 2¾ in. in diameter, and covered with a muslin top was substituted. The enclosure was accidently stripped off during the following night, allowing the "ticks" to escape. Thus three "ticks" which emerged on May 21st (early winter) mated five days later, and extruded their first pupa when thirteen days old.

Experiment No. 4.

On January 12th (mid-summer) sixteen young "ticks," about twelve hours old, were liberated on a lamb housed in one of the pens previously referred to. The lamb had been dipped on December 17th, and shorn and re-dipped on January 3rd. When the experiment commenced the fleece was ½ in. long and free of both living and dead "ticks." The first examination was made three days later (January 15th), when several dead "ticks" were found. The living "ticks" were not counted daily on account of the difficulty experienced in finding them. On the eleventh day (January 23rd) two pairs were found copulating. On the twenty-first day (February 2nd) two pupae were found in the fleece. On the twenty-second day (February 3rd) another pupa was found. On the thirty-first day (February 12th) two more pupae were found. Another was found on the thirty-second day (February 13th). On the thirty-ninth day (February 20th) the host was carefully examined with the object of finding and removing all the surviving "ticks" and their pupae. These numbered three females, six males and two pupae. One of the females contained a large larva, apparently nearly ready for extrusion. These nine "ticks" were then placed on another lamb, previously freed of "ticks," for further observation (see p. 84). Great difficulty was experienced in finding the "ticks" and their pupae, even in such short wool. In this experiment it would appear

that the young "ticks" first mated on the eleventh day, extruded the first pupae about the twenty-first day, their second pupae about the thirty-first day, and their third pupae about the thirty-ninth day.

Experiment No. 5.

An experiment similar to the above in all particulars excepting in the number of "ticks" used was commenced on January 23rd, with twenty-five "ticks," about twelve hours old. The fleece was searched daily, and many dead "ticks" were removed, especially during the first few days. On the fourteenth day (February 6th) one pair was found copulating. On the twentieth day (February 12th) the fleece was carefully searched for "ticks" and their pupae, with the result that only five "ticks" could be found. On the twenty-third day (February 15th) two pupae were found. On the thirty-second day (February 24th) the fleece was very carefully searched to ascertain the number of surviving "ticks," which was three males and two females. Two pupae were found also.

Thus assuming that copulation did not take place earlier than February 6th, and that the four pupae were all extruded by the two females found on February 24th, it will be seen that the first mated when about fourteen days old, extruded the first pupae about the twenty-third day, and the second pupa about the thirty-second day.

Many other experiments similar to, or modifications of, Experiment No. 3, page 80, were undertaken, but in none of them was I able to obtain any useful data. It was found impossible to firmly secure a buckram or muslin enclosure to the host for more than a day at the longest. In one experiment only (No. 3, p. 80) could the "ticks" be kept alive and under observation for a sufficiently long period to enable me to obtain the desired information, and after repeated failures this method was abandoned. Collars made of tin or modelling wax were then tried. With the aid of melted pitch plaster it was found possible to secure these enclosures in position for several days, and, further, as the "ticks" were unable to crawl up the smooth inner surface, it was not necessary to cover the top of the enclosure. The young "ticks," however, soon died in these enclosures, and in no case did one live to reach maturity. The writer's experience with "ticks" confined in small enclosures on the host agree with Swingle's, i.e., such "ticks" will not live for more than a couple of weeks, very rarely so long.

Summary and Observations.

It will be seen from these experiments that the young Louse-fly or "tick" may reach maturity during the early winter thirteen days after its emergence from the pupa. In one experiment (No. 3, p. 80) the young "ticks" were kept very close together, and therefore had an opportunity of copulating as soon as they were sufficiently developed. Copulation took place on the fifth day after their emergence.

In two other experiments (Nos. 4 and 5) carried out in midsummer the young "ticks" copulated on the eleventh and fourteenth days respectively, and reached maturity, i.e., extruded the first pupa, on the twenty-first and twenty-third days respectively. In these two experiments the few "ticks" under observation had access to all parts of the host's fleece, and appeared to be constantly moving from one part of the body to another. Under these conditions the chance of early mating would be greatly reduced, and it is believed that this fact alone accounted for the long period elapsing between their emergence and the deposition of the first pupa as compared with the period ascertained in Experiment No. 3, in which the young "ticks" were kept close together. Swingle (1913, p. 16) found that young "ticks" marked with a silk thread tied around the constriction between the body and thorax and then liberated on the host copulated on the fourth or fifth day during the winter, when the average maximum temperature was 27.3° and the average minimum temperature was 7.2.°. He observes also (p. 23) that young male and female "ticks" are capable of copulating when three days old.

The same investigator (page 18) found that the young female "tick" required a minimum period of fourteen days in which to reach maturity, but he considered that the period might possibly be reduced by carrying out experiments with thousands of "ticks."

3. To determine the length of life of the female.

As previously stated, it was found impossible to keep the "ticks" for any lengthy period within a confined area upon the host; those that were unable to escape soon perished. In one experiment (No. 3, p. 80) young "ticks" were kept for two weeks in an enclosed area, but in all others they died or escaped within a week or less. It was apparent therefore, that some method would have to be devised which would allow the "ticks" a much greater measure of liberty if the desired information was to be obtained.

Following Swingle, the present writer marked some young "ticks" by sticking a very small piece of coloured paper on the dorsum of the abdomen, others with coloured adhesive substances and stains. None of these methods, however, was sufficiently permanent to be of any service. The following method employed successfully by Swingle was then tried:—A short piece of silk thread was separated into its three component strands and tied around the young "ticks" between the thorax and abdomen. The ends were then snipped off close to the knot and the "ticks" were liberated on a lamb previously freed of "ticks." For this purpose young "ticks" which had been fed were employed, as they were less liable to be damaged than very young ones. In most cases the marked "ticks" found their way to the surface of the wool and remained there until they died. In others they remained in the fleece, but did not thrive, and ultimately died. Swingle remarks (p. 21), ". . . if a dozen female 'ticks' be placed in the wool within a circle having a diameter of two inches, the following day they will most generally be found very near that area, at least within a radius of three or four inches." This has not been the present writer's experience here. Even during the winter months the young "ticks" especially showed a very noticeable inclination to wander freely and rapidly, even when encumbered as described above. This fact accounts in a large measure, if not entirely, for the writer's want of success in these experiments.

As a last resort a lamb was shorn and freed of "ticks" after which sixteen young "ticks" were liberated in the fleece (January 12th). The history of these "ticks" up to January 20th is recorded in Experiment No. 4, page 81, where it will be seen that only nine of the original sixteen "ticks" could be found at the end of thirty-nine days. Of those found only three were females. It was intended to keep these nine "ticks" under observation with a view to ascertaining how long they would live and how many pupae each would extrude during its life. As stated on page 81, two of the three "ticks" had already extruded three pupae each, the third contained a larva nearly ready for extrusion. On February 20th these three "ticks" were liberated on a lamb previously shorn and freed of these parasites. On the following day the "tick" containing the large larva was found dead. On the forty-eighth day (March 1st) one pupa was found, but one of the two remaining females could not be accounted for. After two more unsuccessful attempts to find the missing "tick" the experiment was abandoned.

The history of another experiment similar to the above is recorded on p. 82, Experiment No. 5. In this experiment only five "ticks" could be traced at the end of the thirty-second day (February 24th), during which period the two surviving females each extruded two pupae. On February 24th these five "ticks" were liberated on a lamb previously freed of "ticks." On February 26th and two subsequent days only one female and two or three males could be accounted for.

Three other similar experiments were commenced in February and March, but as satisfactory results could not be obtained they were abandoned a few weeks later.

4. To determine the number of pupae extruded by an individual female and the time elapsing between each extrusion.

Attempts to determine the length of life of the female Louse-fly having failed, it is obvious that the number of pupae extruded by an individual female could not be determined. The results of two experiments, however, may be referred to again as indicating the periods elapsing between extrusion of the first and subsequent pupae.

In Experiment No. 4 three young "ticks" which were liberated on a lamb in mid-summer (January 12th) each extruded the first pupa about the twenty-first day, the second pupa about the thirty-first day, and the third pupa (in the case of two "ticks") about the thirty-ninth day. In Experiment No. 5, two young "ticks" each extruded the first pupa about the twenty-third day, and the second pupa about the thirty-second day.

Thus the period which elapsed between the extrusion of each pupa was about nine days (9.14 days). These periods are reckoned from the date of finding of the pupa, which in some cases may have been a day or more after their extrusion; they should be regarded therefore as approximate only. Swingle's investigations in America (1913, pp. 19 and 20), showed that the average rate of pupa laying was one about every eight days (7.89 days in one experiment and 7.99 days in another).

5. To determine the period of viability of the Sheep Louse-fly when removed from the host, (a) unfed flies under one day old, (b) flies from three to seven days old which had fed, (c) adult flies.

A series of experiments with forty-six groups of Sheep Louse-flies kept under thirteen different sets of conditions was commenced in

May, 1917, and continued during the following June, November and December. The insects in Group A were reared from pupae in the laboratory, whilst those in Groups B and C were collected on the host. The ages of the "ticks" in Group B were judged only from their appearance and size. In Group C the required number of adults was selected from mated pairs.

Nature of Receptacles and the conditions under which the "Ticks" were kept.

Experiment No. 6.

A sod of lawn grass in a Petri dish, with a glass chimney 6.4 cms. high and 6.2 cms. wide, firmly embedded in the middle to form an enclosure. The enclosed area was kept moist by water poured on the sod outside the chimney. This receptacle was kept in a cellar under the Institute buildings.

Experiment No. 7.

This receptacle was prepared in the same manner as No. 6, but it was placed under a table on the lawn within the Institute quadrangle.

Experiment No. 8.

Soil in Petri dish, pressed down to form a level surface, upon which a few dry leaves were placed. Position as in No. 7.

Experiment No. 9.

Receptable prepared as in No. 8, but placed in cellar, as in No. 6.

Experiment No. 10.

Prepared similarly to Nos. 8 and 9, excepting that no leaves were placed on the surface of the soil. The position was on the lawn, as in Nos. 7 and 8.

Experiment No. 11.

As in No. 10, but placed in cellar, as in Nos. 6 and 9.

Experiment No. 12.

Sheep's wool (about one handful) placed in an open Petri dish on laboratory table.

Experiment No. 13.

Sheep's wool, as above, but kept in cellar.

Experiment No. 14.

A small wooden box measuring $6\frac{1}{4}$x4x$3\frac{1}{2}$ in., containing one inch of sheep-yard sweepings resting upon one inch of moist soil, the top covered with muslin, placed on the wooden floor of a shelter-house in the sheep yard.

Experiment No. 15.

A wire gauze cage 4 in. in diameter by 5 in. high resting on the natural surface of a sheep-yard, which was sheltered on one side by a wall but otherwise exposed to all weather conditions excepting the rays of the sun during the afternoon.

Experiment No. 16.

A piece of dry Eucalyptus tree trunk, 9 in. long by $2\frac{1}{2}$ in. in diameter, covered with loose bark divided lengthwise into two segments and held in position by rubber bands, the whole standing vertically upon a layer of moist sheep-pen sweepings in a dish and placed in the cellar.

Experiment No. 17.

As in No. 16, but placed upon a table on the lawn, as in Nos. 7, 8, and 10.

Experiment No. 18.

A square jar about 7 in. across the opening, containing about 2 in. of moist sheep-pen sweepings, and placed on the floor of a shelter-house in sheep yard, as in No. 14.

Details of these experiments are recorded in the following statement :—

No.	Position	No. and Age.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.														
6A	Lawn Grass.	10 under	* 50°	50°	...	51.5°	53°	53°	51°	51°	50°	...	51°	...	...	...	...
	In cellar	1 day old	$3^{2♂}_{1♀}$	1♂	...	$2^{♂}_{♀}$	...	1♂	...	...	$2^{♂}_{♀}$	...	1♀	...	...	...	...
6B	Lawn Grass.	25 about	* 50°	50°	...	51.5°	53°	53°	51°	51°	50°	..	51°	50°	...	...	...
	In cellar	7 days old	$2^{♂}_{♀}$	1♂	..	1♂	$3^{2♂}_{1♀}$	$7^{6♂}_{1♀}$	$2^{♂}_{♀}$	$6^{3♂}_{3♀}$	1♂	...	1♀	1♀	...	...	...
6C	Lawn Grass.	25 adults	* 50°	50°	...	51.5°	53°	53°	51°	51°	50°	...	51°	50°	...	...	...
	In cellar		...	...	...	3♀	$4^{1♂}_{3♀}$	$5^{4♂}_{1♀}$	$4^{2♂}_{2♀}$	2♀	2♀	1♀	...	...	...	...	...
7A	Lawn Grass.	10 under	‖ 42°	39°	...	42°	56°	...	...	...	...	...	...	...	...	...	...
	On lawn	1 day old	$4^{3♂}_{1♀}$	$2^{♂}_{♀}$	...	$3^{2♂}_{1♀}$	...	1♀	...	...	...	...	...	...	...	...	...
7B	Lawn Grass.	25 about	‖ 42°	39°	...	42°	56°	...	...	...	...	...	...	...	...	...	...
	On lawn	7 days old	2♂	2♂	...	$14^{10♂}_{4♀}$	$4^{3♂}_{1♀}$	$2^{♂}_{♀}$	1♀	...	...	...	...	...	...	...	...
7C	Lawn Grass.	18 adults	‖ 42°	39°	...	42°	56°	...	...	...	...	...	...	...	...	...	...
	On lawn		...	1♂	...	$3^{2♂}_{1♀}$	$4^{2♂}_{2♀}$	$3^{2♂}_{1♀}$	1♀	$4^{1♂}_{3♀}$	2♀	...	...	...	...	...	...
8A	Soil, with leaves on	2 under	‖ 32.5°	...	42°	48°	40°	45°	..	...	...	...	...	...	...	...	...
	surface. On lawn	1 day old	...	...	1♂	...	...	1♀	...	...	...	...	...	...	...	...	...
8B	Soil, with leaves on	2 under	‖ 51°	50°	42°	35°	...	...	...	...	...	...	...	...	...	...	...
	surface. On lawn	1 day old	...	...	1♀	1♀	..	...	...	...	...	...	...	...	...	...	..

Nos. 6A, 6B, 6C, 7A, 7B, 7C, late June; 8A, late May; 8B, early June.

* Minimum Temperature (Fahr) in Cellar. ‖ Minimum Temperature (Fahr.) in Sheep Yard.

No.	Position	No. and Age.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.														
8c	Soil, with leaves on surface. On lawn	19 about 3 days old	‖ 32.5° 1 ♂	... ...	42° 6 3♂ 3♀	48° 1 ♂	40° 6 3♂ 3♀	45° 1 ♂	51° 3 ♂	52° 1 ♀	... ...	... ...	... ...	... ...	... ...	... ...	... ...
8D	Soil, with leaves on surface. On lawn	20 adults	‖ 35° ...	... ...	46° 2 ♂ ♀	44° 3 1♂ 2♀	44° 6 3♂ 3♀	48° 1 ♂	47° 1 ♀	... 4 3♂ 1♀	... ...	46° 3 ♀	... ...	... ...	... ...	... ...	... ...
9A	Soil, with leaves on surface. In cellar	8 under 1 day old	* 50° ...	51° ...	... ...	51° ...	52° ...	53° ...	53° ...	54° 1 ♂	56° 2 ♂ ♀	... ...	... 1 ♀	56° 2 ♀	56° 1 ♀	57° 1 ♀	... ...
9B	Soil, with leaves on surface. In cellar	6 about 3 days old	* 50° ...	51° ...	... ...	51° ...	52° 1 ♂	53° 2 ♂ ♀	53° 1 ♂	54° 1 ♀	56° 1 ♀	... ...	... ...	... ...	... ...	... ...	... ...
9c	Soil, with leaves on surface. In cellar	26 adults	* 51° ...	... ...	51° 1 ♂	52° 8 3♂ 5♀	53° 4 1♂ 3♀	53° 4 2♂ 2♀	51° 1 ♀	56° 3 ♀	... ..	... 3 1♂ 2♀	56° 1 ♀	56° 1 ♀	... ...	... ...	... ...
10A	Soil, no leaves on surface. On lawn	5 under 1 day old	‖ 35° ...	... ...	46° 1 ♀	44° 2 ♂ ♀	44° 2 ♂ ♀	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
10B	Soil, no leaves on surface. On lawn	9 about 5 days old	‖ 50° ...	42° ..	35° 4 ♂	... ...	46° 5 3♂ 2♀	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	.. ...	... ...
10c	Soil, no leaves on surface. On lawn	25 about 7 days old	‖ 35° ...	32.5° 1 ♂	43° 6 ♂	42° 13 7♂ 6♀	39° 2 ♂ ♀	... ...	42° 3 1♂ 2♀	... ...	... ...	... ...	... ...	... ..	... ...	... ...	... ...

Nos. 8c, 9A, 9B, 9c, late May; 8D, 10A, 10B, early June; 10c, late June.

‖ Minimum Temperature (Fahr.) in Sheep Yard * Minimum Temperature (Fahr.) in Cellar.

No.	Position	No. and Age.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.														
10D -	Soil, no leaves on - surface. On lawn	16 adults -	‖ 35° ...	... ...	46° 1 ♀	44° 6 (2 ♂ 4 ♀)	44° 4 (1 ♂ 3 ♀)	48° 1 ♀	47° 2 ♀	... ...	... ...	46° 2 ♀	... ...	... ...	... ...	... ...	... ...
11A -	Soil, on leaves on - surface. In cellar	5 under 1 day old -	* 54° ...	... ...	53° ...	53° 2 ♂ ♀	50° 1 ♀	50° 1 ♂	53° 1 ♂	... ...	.. ...	... ...	... ...	... ...	... ...	... ...	... ...
11B -	Soil, on leaves on - surface. In cellar	8 about 5 days old -	* 57° ...	54° ...	54° 1 ♂	... ...	53° 4 (2 ♂ 2 ♀)	53° ...	50° 1 ♂	50° 1 ♂	53 ...	46° ...	... ...	... 1 ♀	... ...	... ...	... ...
11C -	Soil, no leaves on - surface. In cellar	20 adults -	· 54° ...	... ...	53° 1 ♂	53° 3 (2 ♂ 1 ♀)	50° 2 ♀	50° 4 (1 ♂ 3 ♀)	53° ...	... 3 (1 ♂ 2 ♀)	... ...	52° 4 (3 ♂ 1 ♀)	52° 1 ♂	50° 2 ♀	... ...	... ...	... ...
12A -	Wool on Laboratory - table	10 under 1 day old -	‡ 52° 10 (3 ♂ 7 ♀)	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
12B -	Wool on Laboratory - table	10 about 7 days old -	‡ 45° 3 (1 ♂ 2 ♀)	... ...	45° 6 (2 ♂ 4 ♀)	50° 1 ♂	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
12C -	Wool on Laboratory - table	102 adults -	‡ 52° 94 (41 ♂ 53 ♀)	48° 8 (5 ♂ 3 ♀)	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
12D -	Wool on Laboratory - table	25 adults -	‡ 43° 18 (7 ♂ 11 ♀)	42° 7 ♀	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...

Nos. 10D, 11A, 11B, 11C, 12A, 12B 12C, early June; 12D, late June.

* Minimum Temperature (Fahr.) in Cellar. · Minimum Temperature (Fahr.) in Sheep Yard ‡ Minimum Temperature (Fahr.) in Sheep Stall.

No.	Position	No. and Age.	Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13A -	Wool in cellar -	7 under 1 day old -	* 57° $6^{3♂}_{3♀}$	54° 1 ♀	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
13B -	Wool in cellar -	10 about 7 days old -	* 57° $10^{5♂}_{5♀}$	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
13C -	Wool in cellar -	20 adults -	* 57° $18^{4♂}_{14♀}$	54° $2^{♂}_{♀}$	... ...	... ..	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
13D -	Wool in cellar -	25 adults -	* 49° $8^{4♂}_{4♀}$	50° $17^{8♂}_{9♀}$	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
14A -	Sheep-pen sweepings - in sheep shelter	12 under 1 day old -	‖ 52° 1 ♂	51° 2 ♂	... $2^{♂}_{♀}$	50° 1 ♂	42° $3^{1♂}_{2♀}$	35° ...	... $3^{1♂}_{2♀}$	46° ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
14B -	Sheep-pen sweepings - in sheep shelter	7 about 7 days old -	‖ 50° ...	42° 1 ♂	35° $2^{♂}_{♀}$	... ...	46° 1 ♂	46° $2^{♂}_{♀}$	44° 1 ♂	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
14C -	Sheep-pen sweepings - in sheep shelter	20 about 7 days old -	‖ 35° ...	32.5° $11^{5♂}_{6♀}$	43° ...	42° $3^{2♂}_{1♀}$	39° 1 ♂	... ...	42° $3^{2♂}_{1♀}$	56° 1 ♂	... 1 ♀	... ...	... ...	... ...	... ...	... ...	... ...
14D -	Sheep-pen sweepings - in sheep shelter	11 adults -	‖ 50° ...	42° ...	35° 2 ♀	... ...	46° 7 ♀	44° ..	44° ...	48° 1 ♀	47° ...	... 1 ♀	.. ...	... ...	... ...	... ...	... ...

Nos. 13A. 13B, 13C, 14A, 14B, 14D, early June; 13D, 14C, late June.

* Minimum Temperature (Fahr.) in Cellar. ‖ Minimum Temperature (Fahr.) in Sheep Yard.

No.	Position	No. and Age.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.														
15A	Surface soil in sheep yard	10 under 1 day old	‖ 50°	42°	35°	...	46°	44°	44°	...	...	...	...	...	...	...	...
			...	1♂	$3^{1♂}_{2♀}$	...	$3^{2♂}_{1♀}$	1♂	2♀	...	...	...	...	...	...	...	...
15B	Surface soil in sheep yard	12 about 1 day old	§ 55°	59°	50°	...	...	...	...	...	...	...	...	...	...	...	...
			$4^{1♂}_{3♀}$	$5^{3♂}_{2♀}$	3♀	...	...	...	...	...	...	...	...	...	...	...	...
15C	Surface soil in sheep yard	10 about 7 days old	‖ 50°	42°	35°	...	46°	44°	44°	48°	...	...	...	...	...	...	...
			...	$4^{2♂}_{2♀}$	1♂	...	1♂	2♂♀	...	2♀	...	...	...	...	...	...	...
15D	Surface soil in sheep yard	80 adults	§ 60°	53°	...	52°	52°	..	...	...	...	...	...	...	...	...	...
			$4^{2♂}_{2♀}$	$12^{6♂}_{6♀}$	...	$55^{18♂}_{37♀}$	$7^{3♂}_{4♀}$	...	...	...	...	...	...	...	...	...	...
15E	Surface soil in sheep yard	50 adults	§ 60°	52°	...	...	61°	...	...	...	...	...	...	...	...	...	...
			$3^{1♂}_{2♀}$	$7^{4♂}_{3♀}$	...	$31^{14♂}_{17♀}$	$3^{1♂}_{2♀}$	...	...	...	...	...	...	...	...	...	...
15F	Surface soil in sheep yard	10 adults	‖ 50°	42°	35°	...	46°	44°	44°	...	48°	47°	...	...	...	...	...
			...	...	4♀	...	...	...	3♀	1♀	2♀	...	...	...	...	...	...
16A	Tree trunk with bark. In cellar	10 1-12 hrs. old	* 54°	...	53°	53°	50°	50°	53°	...	...	52°	52°	50°	50°	...	...
			...	...	...	...	$4^{1♂}_{3♀}$	1♀	$2^{1♂}_{1♀}$	...	...	1♀	...	1♀	...	1♀	...
16B	Tree trunk with bark. In cellar	10 about 7 days old	* 54°	...	53°	53°	50°	50°	53°	...	...	52°	52°	50°	50°	...	..
			...	...	...	2♂	2♂♀	1♂	...	...	...	1♀	1♀	...	...	1♀	...

Nos. 15A, 15C, 15F, 16A, 16B, early June; 15B, early December; 15D, 15E, late November.

* Minimum Temperature (Fahr.) in Cellar. ‖ Minimum Temperature (Fahr.) in Sheep Yard. § Minimum Temperature (Fahr.) on Lawn.

No.	Position	No. and Age.	1	2	3	4	5	6	7	8	9	10	11	12	13	17	18
16c -	Tree trunk with bark.	11 adults -	* 54°	...	53°	53°	50°	50°	53°	...	...	52°	52°	50°	50°	...	49°
	In cellar		...	...	...	1 ♀	2 ♂	...	$3^{2♂}_{1♀}$	...	...	1 ♂	1 ♀	2 ♀	...	...	1 ♀
17A -	Tree trunk with bark.	12 under -	‖ 44°	48°	47°	...	...	46°	...	...	...	...	...	...	...	...	...
	On lawn	1 day old	$3^{1♂}_{2♀}$	...	$4^{1♂}_{3♀}$	...	...	1 ♀	3 ♀	1 ♀	...	...	...	...	...	...	...
17B -	Tree trunk with bark.	10 about -	‖ 35°	...	46°	44°	44°	48°	47°	...	...	46°	...	...	...	...	...
	On lawn	7 days old		...	...	$5^{1♂}_{4♀}$	3	...	1 ♂	...	...	1 ♂	...	...	...	...	...
17c -	Tree trunk with bark.	10 adults -	‖ 35°	...	46°	44°	44°	48°	47°	...	...	46°	...	...	...	...	...
	On lawn		...	...	1 ♀	...	4 ♀	...	2 ♀	...	...	2 ♀	1 ♀	...	...	...	...
17D -	Tree trunk with bark.	46 adults -	§ 47°	50°	60°	52°	...	...	...	...	...	...	...	...	...	...	...
	On lawn		$4^{2♂}_{2♀}$	$16^{3♂}_{13♀}$	$13^{4♂}_{9♀}$	$9^{3♂}_{6♀}$	...	1 ♀	...	...	...	...	...	...	...	...	...
18 -	Sheep-pen sweepings - in open jar in sheep shelter	81 adults -	§ 63°	60°	53°	...	52°	52°	47°	50°	60°	52°	...	...	61°	...	...
			...	$16^{14♂}_{2♀}$	$14^{12♂}_{2♀}$	...	$30^{9♂}_{21♀}$	$11^{3♂}_{8♀}$	$3^{1♂}_{2♀}$	...	1 ♀	1 ♀	..	$4^{1♂}_{3♀}$	1 ♀	...	...

Column heading over 1–18: Number and sex of "ticks" which died during each following 24 hours, or fraction of 24 hours.

Nos. 16c, 17A, 17B, 17c, early June; 17D, 18, late November.

* Minimum Temperature (Fahr.) in Cellar. ‖ Minimum Temperature (Fahr) in Sheep Yard. § Minimum Temperature (Fahr.) on Lawn.

Summary and Observations.

The foregoing Experiments may be summarised as follows:—

Experiment.	All the Louse-flies dead in Class A. (Unfed; under 1 day old).	Class B. (Fed; 3-7 days old).	Class C. (Adults).	Season
	Days.	Days.	Days.	
6.—Lawn grass in celllar	11	12	12	Winter
7.—Lawn grass on lawn	6	7	9	,,
8.—Soil with leaves on surface on lawn	(a)6	8	10	,,
	(b)4	—		,,
9.—As above. In cellar	14	9	12	,,
10.—Soil without leaves on surface on lawn	5	(b)5	10	,,
	-	(c)7		,,
11.—As above in cellar	7	12	12	,,
12.—Wool on laboratory table	1	4	(c)2	,,
	—	—	(d)2	,,
13.—As above. In cellar	2	1	(c)2	,,
	—	—	(d)2	,,
14.—Box of sheep-pen sweepings in sheep shelter	7	(b)7	10	,,
	—	(c)9	-	,,
15.—On natural surface of sheep-yard	(a)7	8	(f)9	,,
	—	—	(d)5	Spring
	—	—	(e)5	,,
	(b)3	—		Summer
16.—Tree-trunk in cellar	14	14	18	Winter
17.—As above on lawn	8	10	(c)11	,,
	—	—	(d)6	Spring
18.—Jar of sheep-pen sweepings in sheep shelter	—	—	13	,,

These experiments show conclusively that the period of viability of Melophagus ovinus, the so-called "sheep-tick," when removed from the host is longer than has been generally believed. Curtice (1890, p. 41) found that moderately well fed "ticks" placed in a cotton-stoppered bottle, with some wool, and kept in a room with a temperature, varying between 60°F. and 80°F. all died in less than four days. Other "ticks" placed in wool over damp soil in a flower pot died within the same period. Some young "ticks," which he fed on the back of his hand were kept alive for nearly two weeks, or until their daily feeding was neglected.

Swingle (1912, p. 22) found that "ticks" kept in boxes covered with gauze all died in four days, whether they were kept warm or cold. Young "ticks," before taking a meal were kept a little longer, and in one case he was able to keep one alive for seven days.

Sweet and Seddon (1917, p. 13), kept "ticks" alive off the host for periods of eleven and eleven and three-quarter days on soil in a cellar.

In one experiment the present writer kept an adult "tick" in a cellar alive for eighteen days. In three experiments under similar conditions to the above, two "ticks," one under twelve hours old and unfed, the other about seven days old, lived for fourteen days. In two other experiments a young unfed "tick" and an adult "tick" lived for thirteen days. In the latter case the insect was kept under conditions closely simulating natural surroundings. In yet another experiment a female "tick" which was kept off the host under conditions such as might be found on any sheep run survived to the eleventh day.

Curtice (1890, p. 40) remarks of the "sheep-tick": "It is not at all probable that they can exist many days apart from the sheep as they are unfitted by structure for any other habitat." Herms (1915, p. 294), referring to this insect, says: "When off the sheep the insects die in from two to eight days, most of them dying in about four days."

Swingle (1913, p. 22) goes further, and remarks: "The 'sheep-tick' spends its whole life on the sheep. It is a false idea that the 'tick' may drop off the sheep, and live for a long time in the grass or brush, and be picked up again by sheep sometime later, as is the case with the true tick." Doubtless these statements might be applied in most cases to Australia also, but since it has been shown by Sweet and Seddon and by the present writer that "ticks" remain viable for a longer period off the host than appears to be the case in America and Europe, and in view of the well-known habit of these insects in crawling over the surface of the fleece in warm weather, it would appear very probable that some of them do become dislodged from the host and ultimately find their way back to the sheep. It must be observed, however, that in most cases "ticks" apart from the host do not die rapidly, but weaken gradually until they are no longer able to attach themselves to any object. There is a period, therefore, in the life of such "ticks" during which the individual, owing to physical weakness, would probably not be able to avail itself of an opportunity of continuing its existence on the host.

From an analysis of these experiments it will be seen that the most favourable condition and location for the survival of the adult parasite off the host was a piece of tree trunk resting on sheep-pen sweepings in the cellar in winter; the next most favourable condition was an open jar of sheep-pen sweepings in a sheep shelter in spring; the next was the lawn grass in the cellar, soil with leaves on the surface in cellar, and soil without leaves on the surface in cellar, in all three of which the parasites lived equally long. The most favourable condition was the tree trunk on sheep-pen sweepings on the lawn, where the "ticks" lived eleven days in winter and six days in spring; the next bare soil on the lawn, soil with leaves on the surface, and sheep-pen sweepings in a sheep-shelter, in all three of which the insects died in ten days during the winter. The next most favourable condition was the sod of lawn grass on lawn in winter, and the natural surface of the sheep-yard in winter, where the parasite lived nine days. Under the latter condition in spring, two groups of "ticks" all died in five days. Finally, the least favourable condition was the sheep's wool on the laboratory table and in the cellar, where the insects were all dead in two days.

Influence of age and condition on viability.—It will be seen from the above summary that generally the adult possesses greater vitality than either young fed "ticks," from three to seven days old, or young unfed "ticks," under one day old, and that "ticks" between three and seven days old possess greater vitality than those under one day old. Swingle, as has been stated, found that young "ticks" before taking a meal could be kept alive off the host a little longer than adults. In twelve experiments carried out by the present writer adults outlived unfed "ticks" under one day old; in one experiment the latter outlived the former and in one experiment both classes lived equally long. In ten experiments adults outlived young "ticks" about seven days old; in one experiment the latter outlived the former, and in one experiment they lived for an equally long period. In nine experiments young fed "ticks" between three and seven days old outlived young unfed "ticks" of less than one day old; in two experiments the latter outlived the former, and in one experiment both classes lived for an equally long period.

Influence of sex on viability.—These experiments show that female "ticks" are possessed of greater vitality than males. Both sexes were used simultaneously in forty-two experiments, and in twenty-seven of them the females survived longer than the males. In four experiments the males outlived the females and in eleven experi-

ments both sexes lived for equally long periods. Sweet and Seddon (1917, p. 11), whose observations in this direction were admittedly incomplete, observe that ". . . it is worthy of record that the last surviving 'ticks' were males.

Influence of seasonal conditions on viability.—Experiments carried out in the winter (June), and again in late spring (November) show that the adult "tick" survives outdoor longer in winter than in summer. In the first of these experiments (No. 15) the "ticks" were placed on the natural surface of the soil in a sheep-yard and covered only by a wire-gauze cage. The cage was exposed to all prevailing weather conditions excepting the direct force of the wind from one direction, and from the sun's rays during the afternoon. During the winter all of the "ticks" (ten females) died in nine days; in the early spring, when the average temperature was about 10°F. higher, thirty "ticks" of both sexes all died within five days. In the second experiment (No. 17) in which the "ticks" were kept on the lawn in a dish of sheep-pen sweepings upon which rested a piece of tree trunk, all of the "ticks" (ten females) died in eleven days in winter; in the spring, when the average temperature was about 8°F. higher, all of the "ticks" (forty-six males and females) died in six days.

6. To determine the period of viability of the pupa when removed from the host.

Experiment No. 19.

Eight pupae extruded during the morning of May 28th were kept on moist filter paper and incubated at 34°C. In all six young flies were produced on eighteenth and nineteenth days. The remaining pupae (two) were found to be dead.

Thus 75% of the pupae remained viable, and produced young flies in eighteen to nineteen days from date of extrusion.

Experiment No. 20.

Twenty pupae of unknown ages, collected on November 27th, were placed in a *dry Petri dish* and incubated at 33°C. One young fly, emerged on seventh day, one on eighth day, three on tenth day, and one on eleventh day. The remaining fourteen were found to be dead when examined on December 31st.

Thus 42.8% of the pupae remained viable, and produced young flies seven to eleven days after their removal from the host.

Experiment No. 21.

Ten pupae of unknown ages, collected on August 17th, were kept on *moist sheep-pen sweepings* and incubated at 18°C. to 28°C. Two young flies emerged on tenth day, one on seventeenth day, three on nineteenth day, two on twenty-second day, one on twenty-third day, and one on twenty-sixth day.

Thus 100% of these pupae produced young flies ten to twenty-six days after their removal from the host.

Experiment No. 22.

Thirty-five pupae, known to be less than six days old, were collected on September 19th, and kept on *moist* sheep-pen sweepings in an incubator at temperatures ranging from 26°C. to 32°C. Two young flies emerged on the twelfth day, two on fourteenth day, two on fifteenth day; six on sixteenth day; five on nineteenth day; two on the twentieth day; and one on the twenty-first day.

Thus 57% of the pupae remained viable, and produced young flies within twelve to twenty-one days of their removal from the host.

Experiment No. 23.

Thirty pupae of unknown ages were collected on August 30th, and placed on *dry* sheep-pen sweepings in an incubator at a temperature of 22°C. Two young Louse-flies emerged on fourth day, three on eleventh day, two on eighteenth day, one on nineteenth day, one on twentieth day, and one on twenty-third day. The remaining twenty-one pupae died.

Thus 30% of the pupae remained viable and produced young flies within two to twenty-three days of their removal from the host.

Experiment No. 24.

Thirty pupae of unknown ages were collected on August 30th, placed on *dry sand*, and incubated at a temperature ranging from 18°C. to 28°C. One young emerged each day from the fourth to the sixth day, two flies emerged on seventh day, two on eleventh day, two on fourteenth day, seven between the fifteenth and eighteenth days, two on nineteenth day, and one on twenty-first day. The remaining ten died.

Thus 60.6% of the pupae remained viable, and produced young flies within four to twenty-one days of their removal from the host.

Experiment No. 25.

Twenty-three pupae of unknown ages, collected on October 2nd, were placed on *dry sand*, and incubated at a temperature of 22°C. One young fly emerged on the third day, two on the sixth day, two on the tenth day, two on the thirteenth day, one on the eighteenth day, one on twenty-third day, five on twenty-seventh day, one on twenty-eighth day, two on the thirty-first day, and two on the thirty-second day.

Thus 82.6% of the pupae remained viable, and produced young flies within three to thirty-two days of their removal from the host.

Experiment No. 26.

Fifty pupae of unknown ages, collected on September 7th, were placed on *dry sand*, and incubated at 36°C. Two young flies emerged on the first day. The remaining forty-eight were found to be dead on October 18th.

Thus only 4% of the pupae remained viable, for a period of only one day.

Experiment No. 27.

Thirty pupae of unknown ages, collected on August 30th, were incubated at 22°C. on moist sand. One young fly emerged on the twelfth day, one on the eighteenth day, one on the twenty-third day, and one on the twenty-fifth day. The remaining twenty-six pupae died.

Thus 13.3% of the pupae remained viable, and produced young flies within twelve to twenty-five days of their removal from the host.

Experiment No. 28.

Forty-six pupae of unknown ages, collected on December 7th, were incubated on moist sand at a temperature of 36.°C. None of these produced young flies.

Experiment No 29.

Forty-nine pupae of unknown ages, collected on August 30th, were placed on dry sand in Petri dish, which was placed on the lawn within the Institute quadrangle. The dish was exposed to all the prevailing weather conditions, excepting that the surrounding buildings broke the force of the wind, and that a small table which was placed over the dish prevented the rain falling directly upon the sand. On clear days the pupae were exposed to the direct rays of

the sun, excepting during the morning and late afternoon. One fly emerged on the sixth day, one on the seventh day, and one on eleventh day. The remaining forty-six pupae were found to be dead on November 5th. A thermometer exposed to the above conditions registered a maximum of 68°F., and a minimum of 44°F., during these eleven days, and a maximum of 86°F., and a minimum of 43°F., for the thirty-five days following the commencing date of this experiment.

Thus 6% of these pupae remained viable, and produced young flies from six to eleven days from date of their removal from the host.

Experiment No. 30.

The above experiment was repeated with fifty pupae collected on October 2nd. One young fly emerged on the twenty-second day, one on the twenty-fourth day, and one on thirty-fourth day. On the thirty-fourth day it was found that four pupae were missing (probably taken by birds). The remaining forty-three pupae were then examined and found to be dead.

Thus 6% of the pupae remained viable and produced young flies within from twenty-two to thirty-four days of their removal from the host. During the period the maximum temperature was 86°F. and the minimum 34°F.

Experiment No. 31.

The preceding experiment was duplicated on the same day. None of the pupae produced young flies, and all were found to be dead thirty-eight days later.

Experiment No. 32.

An experiment similar to the three preceding experiments was commenced on November 21st, with thirty-three pupae of unknown ages. None of these pupae produced young flies during the following forty days, at the end of which period they were examined and found to be dead. The maximum temperature recorded for the first eighteen days was 84°F. and the minimum 47°F. For the remaining period (twenty-six days) the maximum was 110°F. and the minimum 50°F.

Experiment No. 33.

Fifty pupae of unknown ages, collected on November 21st, were placed in a loose ball of sheep's wool about $\frac{3}{4}$ in. in diameter in a small, thin muslin bag, which was then tied to a post on the quad-

rangle lawn. The bag, which was 15 in. from the ground, was exposed to all prevailng weather conditions, as in Experiment No. 29. The range of temperature was the same as in the preceding experiment (No. 32). Three young Louse-flies emerged on the third day, one on the twelfth day, one on the sixteenth day, five on the nineteenth day, one on the twenty-fourth day, one on the twenty-sixth day, and one on twenty-seventh day. The remaining thirty-eight pupae were found to be dead on December 31st.

Thus 31.5% of the pupae remained viable, and produced young from three to twenty-seven days from the date of their removal from the host.

Experiment No. 34.

Sixteen pupae collected on August 6th were placed on *moist earth* in a Petri dish, which was kept in a cool dry cellar beneath the Institute building. Throughout the experiment the earth was kept in a moist condition. During the first twenty-five days the temperature ranged from 50°F. to 59°F., and during the remaining period of the experiment (forty-five days) the range was from 52°F. to 60°F. None of the pupae produced young flies, and all were found to be dead when examined seventy days after the experiment was commenced.

Experiment No. 35.

An experiment similar to the above, in which twenty-six pupae of unknown ages, placed on dry earth, was commenced also on August 6th. None of the pupae produced young flies.

Experiment No. 36.

One hundred and eighty pupae, collected on January 9th, were kept on the laboratory bench in a 4 oz. tobacco tin, containing a small quantity of wool. The tin was covered with its lid except when it was necessary to open it for the purpose of counting the young flies. During the experiment the maximum temperature was 90°F. and the minimum 60°F. The pupae were examined on the days mentioned, and the young "ticks" were removed from the tin on these occasions. Two young "ticks" were removed at the end of the first day, eight on the third day, sixteen on the sixth day, seven on the eighth day, eleven on the ninth day, eight on the tenth day, twenty-seven on the twelfth day, three on the fourteenth day, seven on the seventeenth day, ten on the twentieth day, five on the twenty-second day, six on the twenty-third day, four on the twenty-seventh day, three on the thirtieth day, five on the thirty-first day,

four on the thirty-fourth day, two on the thirty-seventh day, one on the thirty-ninth day, and one on the forty-second day. The remaining fifty pupae were found to be dead on February 27th.

Thus 72% of the pupae remained viable, and produced young flies in one to forty-two days after their removal from the host.

Summary and Observations.

The results of these eighteen experiments to determine the viability of the pupa when removed from the host are summarised in the following tabulated statement:—

VIABILITY OF THE PUPA.

Conditions under which pupae were kept.	Experiment No.	Range of Temperature Fahr.	First and last day on which young emerged.		Percentage of pupae which produced young.
On moist sheep-pen sweepings in incubator	21	64.40-82.40	10	26	100.
On dry sand in incubator	25	71.6	3	32	82.6
On moist paper in incubator	19	93.2	18	19	75.
On wool in tin in laboratory	36	60-93	1	42	72.
On dry sand in incubator	24	64.4-82.4	4	21	60.6*
On moist sheep-pen sweepings in incubator	22	78.8-89.6	12	21	57.
In dry petri dish in incubator	20	91.4	7	11	42.8
In wool on post out of doors	33	47.0-84.0	3	27	31.5
On dry sheep-pen sweepings in incubator	23	71.6	4	23	31.
On moist sand in incubator	27	71.6	12	25	13.3
On sand on lawn	29	44.0-68.0	6	11	6.
On sand on lawn	30	34.0-86.0	22	31	4.
On dry sand in incubator	26	96.8	1	—	4.
On sand on lawn	31	34.0-86.0	—	—	0.
On sand on lawn	32	47.0-84.0	—	—	0.
On moist sand in incubator	28	96.8	—	—	0.
On moist earth in cellar	34	50.0-59.0	—	—	0.
On dry earth in cellar	35	50.0-59.0	—	—	0.

NOTE—In all experiments in which the pupae were kept in the incubator a certain amount of humidity was provided by placing a small petri dish of water on the lower shelf.

It will be seen from this statement that under the most favourable conditions 100% of the pupae removed from the host are capable of developing into young Louse-flies. This high percentage of emergences was obtained in one experiment in which the pupae were placed on *moist* sheep-pen sweepings and kept in an incubator at

temperatures ranging from 64.4°F. to 82.4°F. The first young Louse-fly emerged on the tenth day, and others followed until the twenty-sixth day, when the last emerged.

The next highest percentage of emergences was obtained in an experiment in which the pupae were placed on *dry sand* in an incubator at a uniform temperature of 71.6°F.; under these conditions 82.6% of the pupae developed into Louse-flies, the first on the third day and the last on the thirty-second day.

The next most favourable condition for the development of the pupae was a temperature of 93.2°F., and the substitution of moist paper for dry sand. Under these conditions 75% of pupae less than one day old when gathered from the host emerged on the eighteenth and nineteenth days. A slightly lower percentage of emergence, namely, 72%, was obtained when the pupae were kept in a covered tin on the laboratory table, where the temperature ranged from 60°F. to 90°F. In this experiment the first Louse-fly emerged on the first day and the last on the forty-second day. When the pupae were kept on dry sand in the incubator at a temperature ranging from 64.4°F. to 82.4°F., 60.6% of them developed into the imaginal state—the first on the fourth day and the last on the twenty-first day. On moist sheep-pen sweepings in an incubator, at temperatures ranging from 78.8°F. to 86.9°F., 57% of the pupae experimented with produced Louse-flies, the first of which emerged on the twelfth day and the last on the twenty-first day; 42.8% of the pupae which were incubated in a dry dish at 91.4°F. produced Louse-flies, the first of which emerged on the seventh and the last on the eleventh day. The next most favourable condition for development was in wool on a post out-of-doors, at a season of the year during which the temperature ranged from 47°F. to 84°F.; 31.5% of the pupae produced young Louse-flies, the first of which emerged on the third day and the last on the twenty-seventh day. This result, it will be noticed, is of particular interest, inasmuch that the conditions under which the experiment was carried out closely simulated natural conditions. Only a very slightly lower percentage of emergences, namely 31%, was obtained in an experiment in which the pupae were placed on dry sheep-pen sweepings in an incubator at a temperature of 71.6°F. Under these conditions the first pupa developed into a young "tick" on the fourth day and the last on the twenty-third day.

In two experiments under almost natural conditions—namely, on sand on the lawn—only 6% of the pupae developed. In one of the

experiments, during which the temperature ranged from 44°F. to 68°F., the first pupa developed into a young "tick" on the sixth day and the last on the eleventh day. In the other experiment, during which the temperature varied from 34°F. to 86°F., the first "tick" did not appear until the twenty-second day and the last not until the thirty-fourth day.

The experiment which gave the lowest percentage of emergences was one in which the pupae were placed on dry sand and incubated at a temperature of 96.8°F. Under these conditions 4 % of the pupae developed into Louse-flies, namely two of a total of fifty. Both emergences took place during the first day.

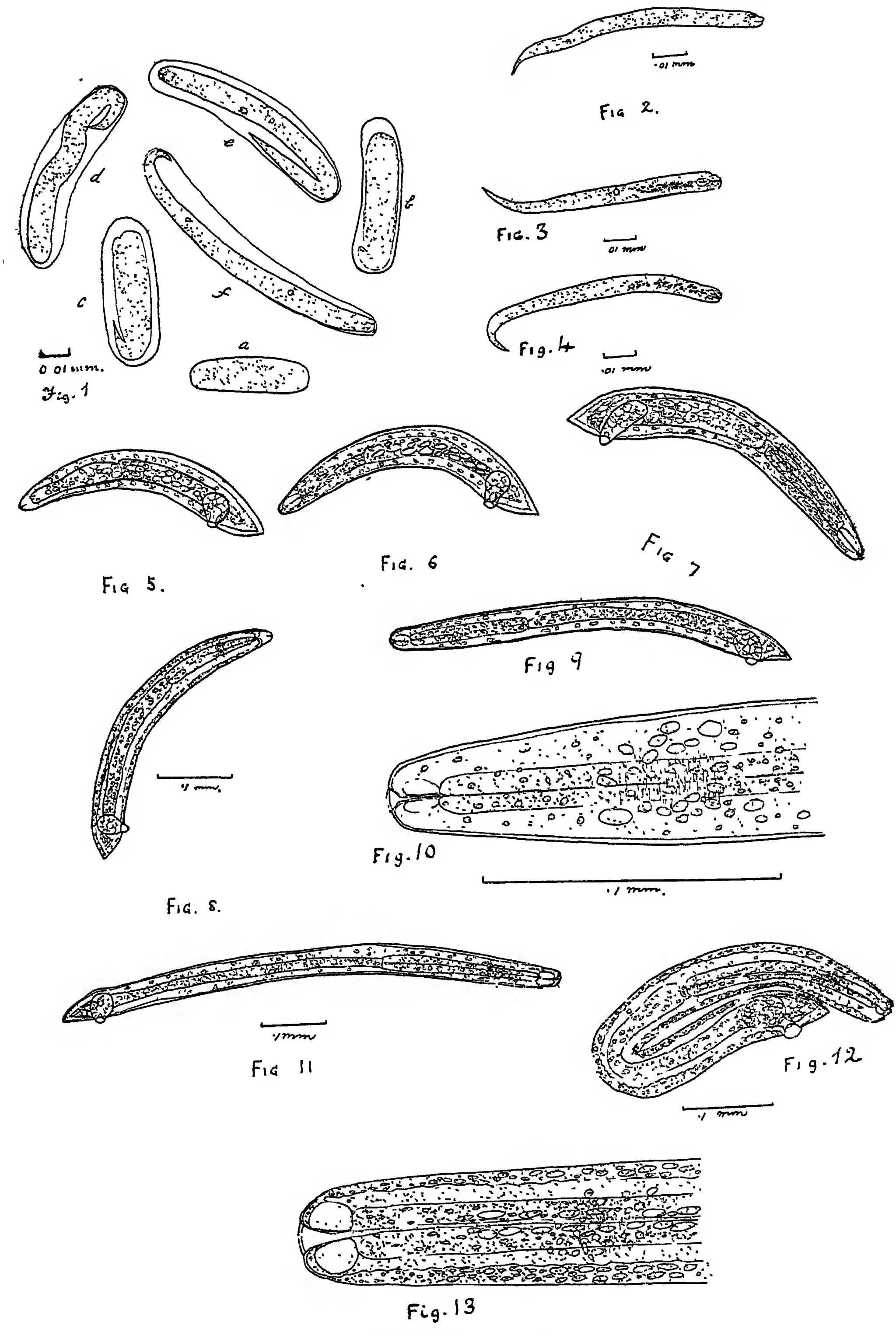
Under the following five sets of conditions the development of the pupa was absolutely inhibited, namely, (1) pupae on moist sand in incubator at 96.8°F., (2) on sand on lawn at temperatures varying from 34°F. to 86°F., (3) on sand on lawn at temperatures varying from 47°F. to 84°F., (4) on moist sand in cellar at temperatures varying from 50°F. to 59°F., and (5) on dry earth in cellar at temperatures varying from 50°F. to 59°F.

General Summary and Discussion.

As is well known, the members of the family Hippoboscidae, to which the Sheep Louse--fly belongs, are all parasitic in the adult stage upon birds or mammals, and as in the other families of the Sub-order Pupipara, the larva is retained in the body of the female until it is nearly ready to transform into the pupal stage.

Unlike the true tick, which leaves the host to oviposit, the Sheep Louse-fly, or "sheep-tick," spends its whole life upon the host. The nearly fully developed larva is extruded into the wool, where it transforms, about twelve hours later, into a pupa, from which it is, however, externally indistinguishable except in hardness and colour. This pupa, or more correctly puparium, since the pupa is enclosed within the larval skin, is securely attached to the fleece by a glutinous substance which is extruded by the female with the nearly fully developed larva.

The incubation period of the pupa varies according to temperature. On sheep kept here in a stall in winter, when the temperature varied from 43°F. to 47°F., the period was found to be from twenty-two to twenty-four days. In summer, when the temperature varied from 47°F. to 72°F., the period on stalled sheep was found to be nineteen to twenty-one days.



Habronema muscae.

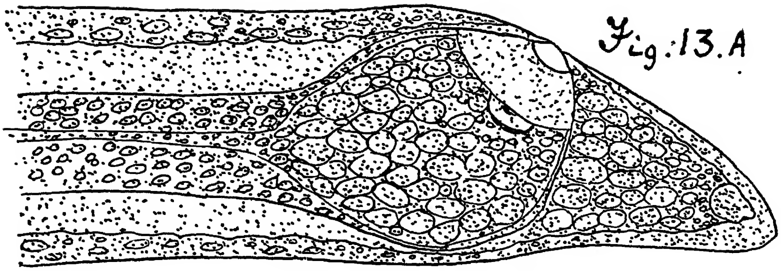


Fig. 13. A

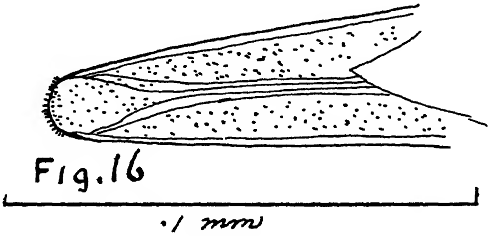


Fig. 16

Fig. 17.

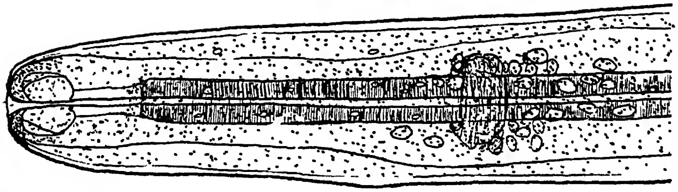


Fig. 14

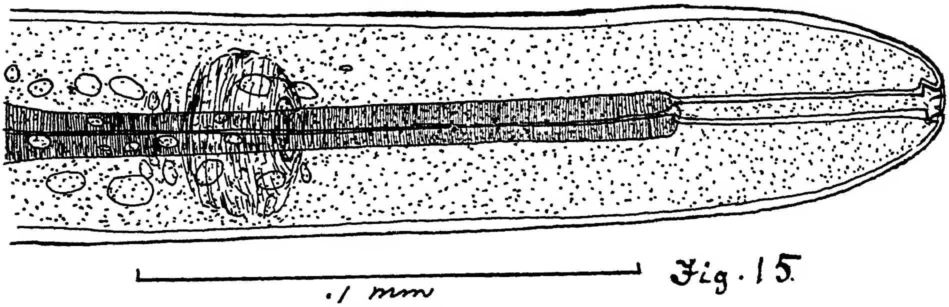


Fig. 15.

Habronema muscae.

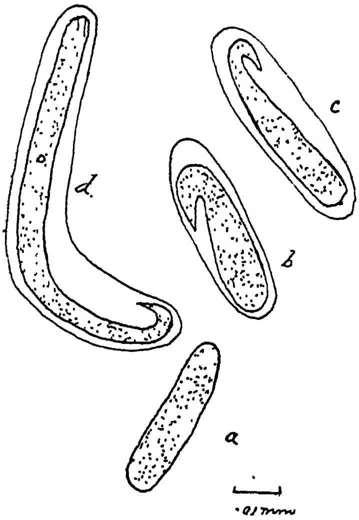


Fig. 18.

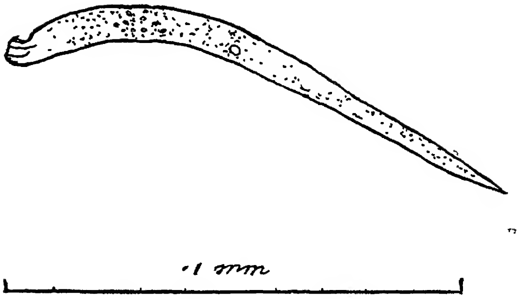


Fig 19

Fig 20.

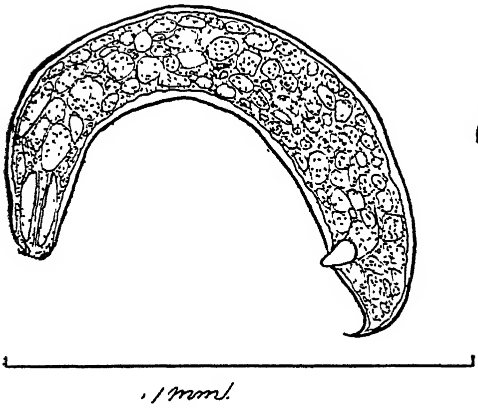


Fig. 21.

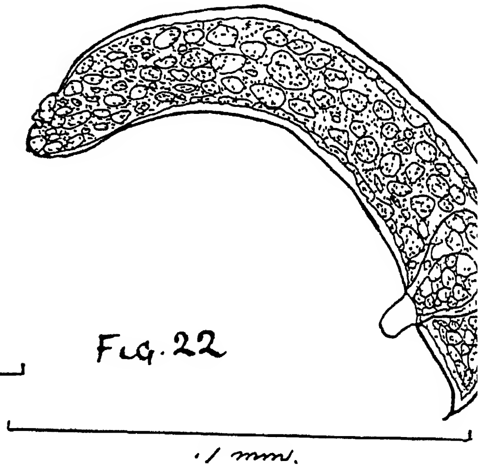


Fig. 22

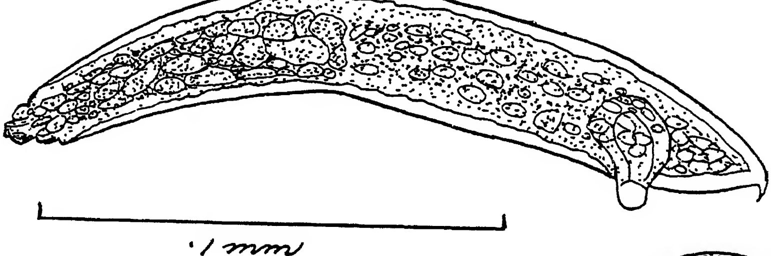


Fig. 23.

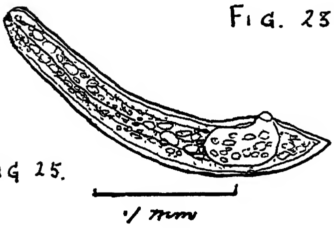


Fig 25.

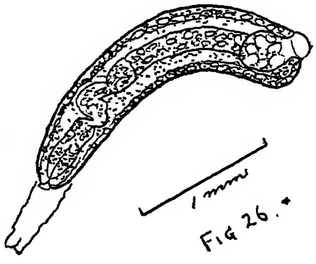


Fig 26.

Habronema microstoma.

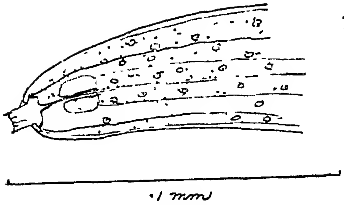


Fig 27

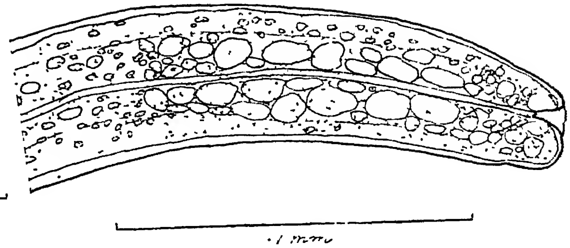


Fig. 24

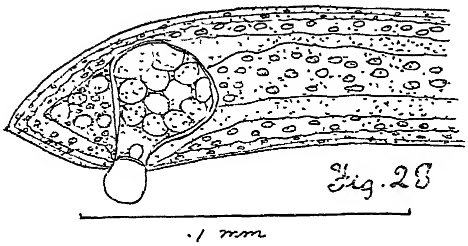


Fig. 28

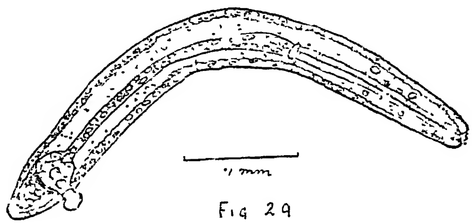


Fig 29

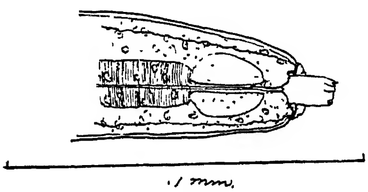


Fig. 30.

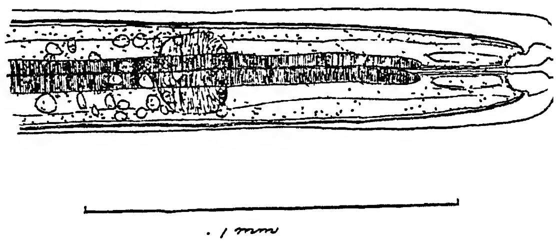


Fig 31

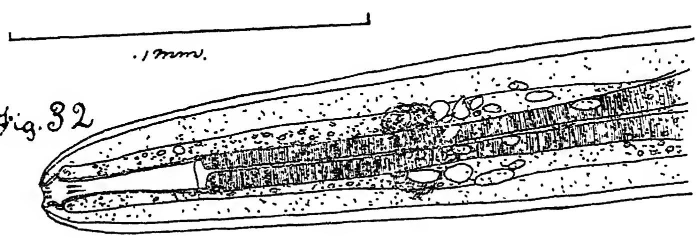


Fig. 32

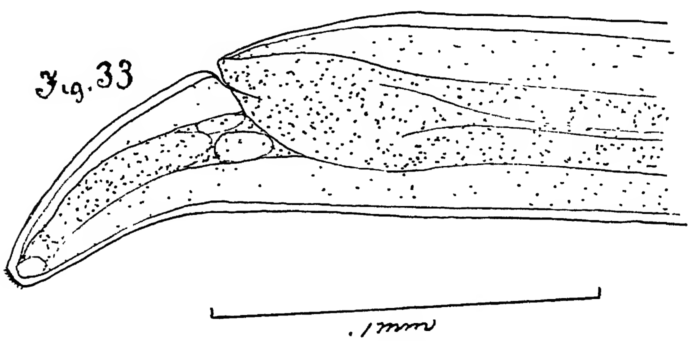


Fig. 33

Habronema microstoma.

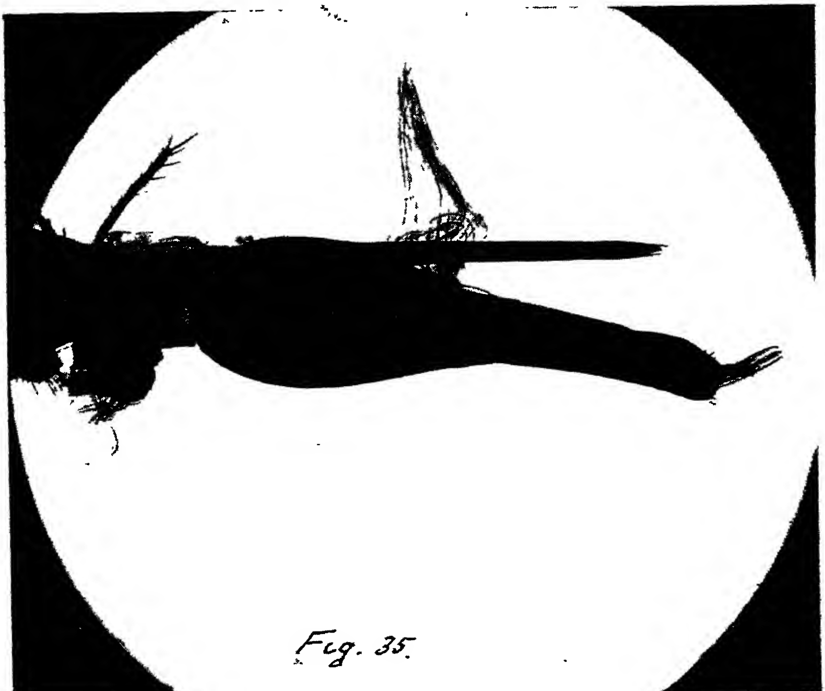


Fig. 35.

Fig. 34.

Proboscis of Stomoxys with Habronema.

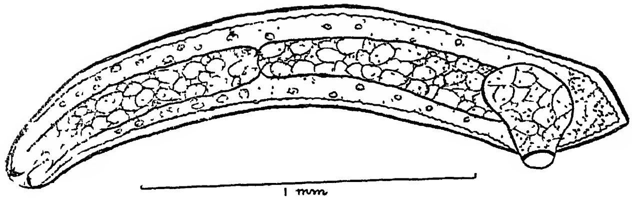


Fig 39

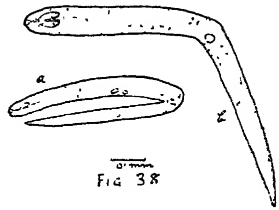


Fig 38

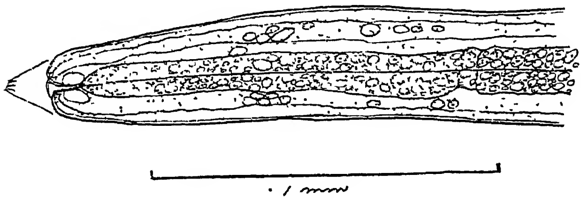


Fig 40

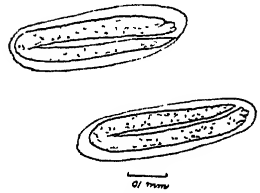


Fig 37

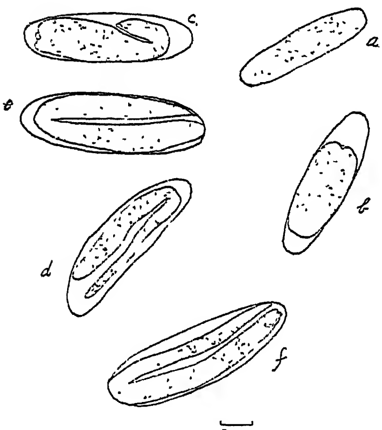


Fig 36.

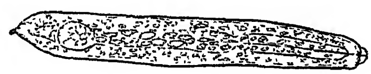


Fig. 41.

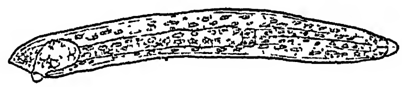


Fig 42.

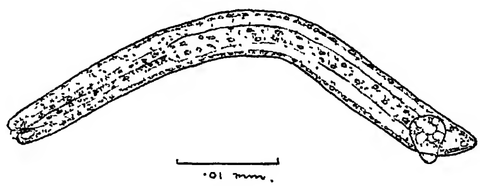


Fig 43.

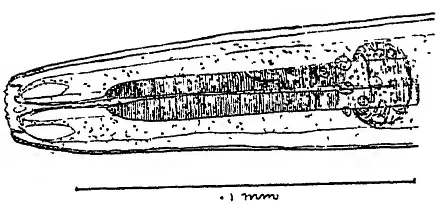


Fig 45

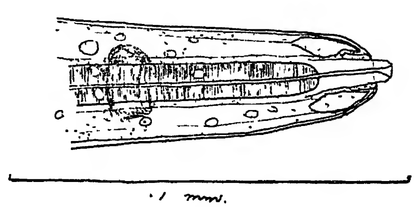


Fig 44

Habronema megastoma.

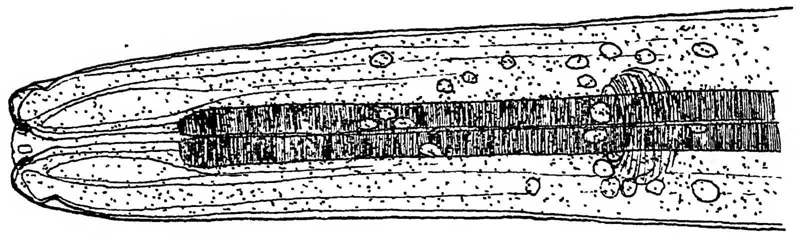
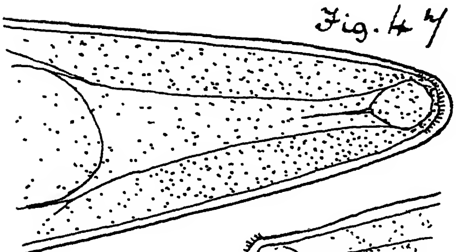
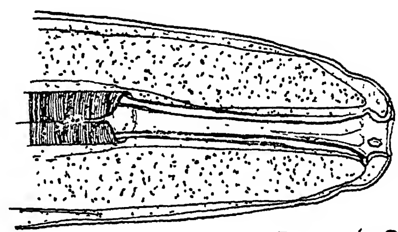


Fig. 46

·1 mm

Fig. 47





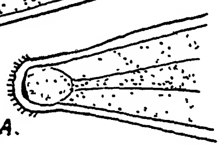
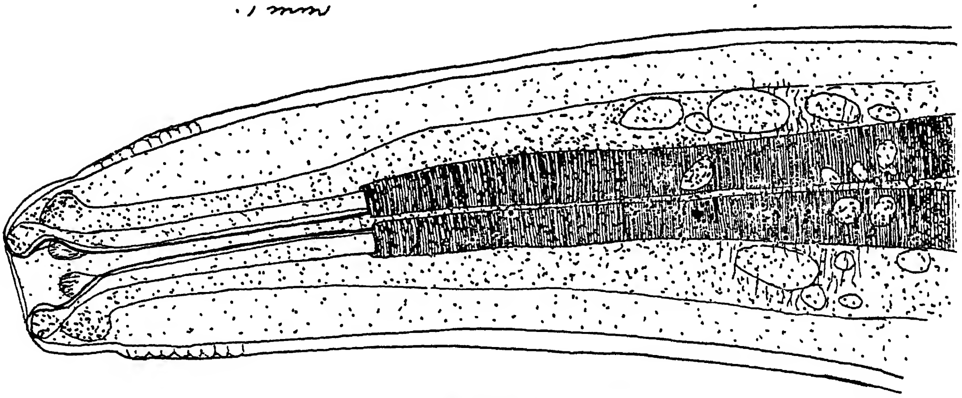


Fig. 48

·1 mm.

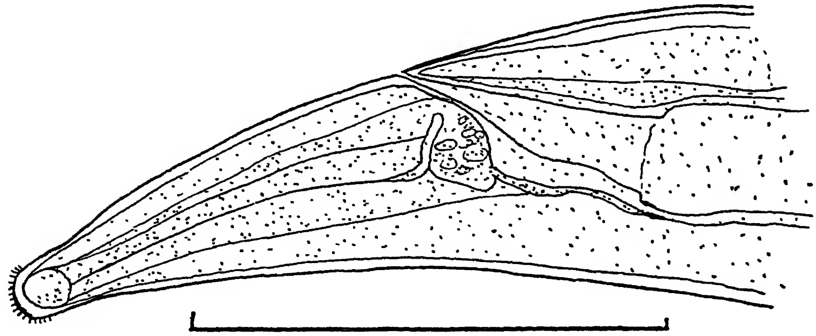
Fig. 48A.

·1 mm



·1 mm.

Fig 49



·1 mm

Fig. 49 A.

Habronema megastoma.

Young female Louse-flies are capable of copulating five days after their emergence from the pupae, but when a few insects only are liberated on, and allowed access to all parts of, the host, the period is usually longer, owing to the chances of early mating being lessened. Under these conditions mating has been found to take place on the sixth to fourteenth day.

The young female extrudes the first pupa in a minimum period of thirteen days after her emergence from the pupa. The usual period, however, is longer, i.e., up to twenty-three days.

It has not yet been found possible to determine here the length of life of, and the number of pupae extruded by an individual female Louse-fly. No positive results therefore can be given as to the average period elapsing between the extrusion of each pupa during the whole life of an individual Louse-fly under the conditions of these investigations except that it would appear that pupae may be extruded, for a time at least, at an average rate of one every nine days.

The period of viability of the Sheep Louse-fly when removed from the host and kept without food is longer under Southern Australian conditions than has been recognised elsewhere. European and American authors and investigators, whose works are available here for reference, are agreed that the Sheep Louse-fly does not live to the eighth day, and that most of them die in from two to four days. Sweet and Seddon showed that these insects could be kept alive off the host in Victoria for eleven and three-quarter days under cool uniform conditions in early summer. The present writer's investigations show that even this latter period may be exceeded, as was the case in no less than ten of the forty-six groups of Louse-flies experimented with.

The adult Louse-fly lives longer apart from the host than does either the unfed insect under one day old or the young insect of three to seven days old which has fed upon the host. The female in nearly all cases outlives the male.

The longest period for which an adult female has been kept off the host and without food is up to the eighteenth day. This "tick" was kept in a dish of sheep-pen sweepings, containing portion of a tree-trunk, in a dry, well-ventilated cellar, where the temperature was very uniform in contrast to extremes above and below in outside temperatures.

Under similar conditions groups of Louse-flies under one day old (unfed) and from three to seven days old (fed) all died in fourteen

days, which is the longest period for which these classes have been kept.

Under more natural out-of-door conditions the maximum time of survival was, for adult "ticks," eleven days, for three to seven days old (fed) "ticks" ten days, and for one day old (unfed) "ticks" eight days, on a small part of a tree-trunk with loose bark on a sheltered lawn, and ten, eight, and seven days respectively when on surface of soil on same lawn, though in each case the majority of the "ticks" died before the end of the fourth or fifth days.

Excepting under the influence of extremes of temperature, a certain proportion of the pupae are viable for varying periods up to forty-two days after removal from the host.

The percentage of pupae which retain their viability off the host varies very greatly with the influence of temperature. When pupae were placed on moist sheep-pen sweepings and incubated at temperatures varying from 64.4°F. to 82.4°F., 100% produced young Louse-flies between the tenth and twenty-sixth day. Under more natural conditions, the percentage was found to be lower, for example, pupae which were placed in a small quantity of wool on a fence post out of doors, where the temperature varied from 47°F. to 84°F., produced 31.5% of young flies between the third and twenty-seventh day. On sand out of doors, two groups of pupae produced only 6% of young flies. In all other out-of-door experiments, pupae failed to develop when removed from the host.

The experiments and observations recorded in the preceding pages show that there is some slight ground for the contentions of those sheep-owners who maintain that sheep previously freed of Louse-flies by dipping may become reinfected with other "ticks" which have been left on grass, bushes or posts, etc., or with young "ticks" which have emerged from pupae dislodged from the fleeces of infected sheep. The present writer, however, cannot find any record of Louse-flies or their pupae having been found under such circumstances, though the transference of the adult insects from the fleece to bushes, posts, logs, etc., appears to be extremely probable in view of the habit of these insects in coming to the surface of the fleece in warm weather. It is quite conceivable also that a few pupae are dislodged whilst the host is engaged rubbing against fence-posts, branches, etc.

Possibly other pupae fall from the fleece to the ground as a result of the dipping fluid or heavy rain dissolving the glutinous matter

which attaches them to the wool. Even under favourable conditions the number of "ticks" which survive for more than four or five days off the host and subsequently reinfect "tick"-free sheep must be extremely small, much too small to account for a general reinfection of a clean flock or even a moderately large number of its members.

The writer is of opinion that while a certain amount of re-infection is not only possible, but very probable, most of the parasites found on previously dipped sheep are the progeny of pupae extruded prior to dipping, and which have escaped the destructive action of the fluid. That this sometimes does happen at least with some ordinary dipping fluids is well known to the writer, insomuch that all sheep used in these experiments had to be dipped twice, even though strong solutions were used for the first dip, namely, L.C.S. or Cyllin, in the proportion of 2 ozs. to one gallon of water.

Acknowledgement.

In conclusion, I desire to record my appreciation of the courteous assistance accorded me by Professor H. A. Woodruff, Director, Dr. Georgina Sweet, D.Sc., Lecturer in Parasitology, and Mr. H. R. Seddon, B.V.Sc., Lecturer in Pathology and Bacteriology of this Institute, during the progress of these investigations and in the preparation of this Report.

I am especially indebted to Dr. Sweet for devoting much valuable time to the examination of Helminth material, for advice, and a generous measure of aid in the conduct of these experiments, and in the preparation of this Report for publication, without which assistance my task would have been impossible.

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[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART I, 1918].

ART. V.—*Ostracoda from the Upper Cambrian Limestone of South Australia.*

By FREDERICK CHAPMAN, A.L.S., &c.
(Palaeontologist, National Museum, Melbourne).

(With Plate IX.).

[Read May 9th, 1918].

Sources of the Collection.

In January, 1903, Mr. George Sweet, F.G.S., of Brunswick, kindly placed a series of leperditioid fossils in my hands for description. The specimens, numbering about twenty-two, were collected by Mr. Sweet from the Upper Cambrian *Archaeocyathina* Limestone at Curramulka, South Australia.

Subsequently, in January, 1906, Mr. Walter Howchin, F.G.S., of the Adelaide University, was good enough to send me a tablet of similar ostracodal remains from the same locality; and quite recently he supplemented these with two others. These mounted specimens from the Adelaide Museum presumably included the two forms mentioned by Prof. Ralph Tate in his paper, " On the Cambrian Rocks at Curramulka."[1] and to which reference will be found in the descriptive part of this paper.

Generic Affinities of the Species.

After a rather prolonged study of these difficult forms I have concluded that they represent both *Leperditia* and *Isochilina*. The former genus is more usually met with in Ordovician and Silurian strata, and occasionally in Devonian and Carboniferous beds, but is not unknown from the Upper Cambrian notwithstanding that E. O. Ulrich in Eastman-Zittel[2] gives the range " Ordovician to Carboniferous." That the genus *Leperditia* was already established in Upper Cambrian times is seen from the following references:—

In the Calciferous Sandstone of Grande Isle, Grenville and Hawkesbury, Canada, which is equivalent to the Tremadoc Slate of the Upper Cambrian, *Leperditia canadensis* occurs, together with *Beyrichia logani* and *Isochilina ottawa*. *Leperditia anna* is found in similar beds in St. Ann, Canada.[3]

1 Trans. Roy. Soc. South Austr., vol. xv., 1892, p. 187.
2 Text-book of Palaeontology, vol. i., 2nd ed., 1913, p. 737.
3 See Rupert Jones. Ann. Mag. Nat. Hist., ser. 3, vol. i., 1858, pp. 244, 247.

From the Lower Cambrian of the State of New York, Walcott[1] obtained a leperditioid form (*Leperditia dermatoides*), having a punctate surface, which, as Walcott suggested, might represent a new genus. Subsequently, *L.dermatoides* was made the type of the genus *Indiana* by G. F. Matthew.[2] It was to this species that comparison of a South Australian form from Curramulka was made by Prof. Tate,[3] but which is probably referable to a species of *Isochilina.*

The *Leperditia troyensis* of Ford,[4] from the Middle Cambrian of New York State, is now referred to the phyllocarid genus *Aristozoe*, by C. D. Walcott.[5]

It is a striking fact with regard to two *Leperditiae* now recorded from South Australia, that they represent southern hemisphere forms of two distinct types of the genus, both of which are found in Canada, namely, a short suboval form, like *L.anna,* and another, subrhomboidal and oblique, resembling the species described as *L.canadensis.*

The form here referred to *Isochilina*, was relegated to that genus only after some consideration. However, the apparently equal valves and grooved and flattened edges are more in keeping with the characters of this genus rather than with other related generic forms, although it may have later to be given a new genus name. A very useful list of the known *Isochilinae* is given by Prof. Rupert Jones in the Geological Magazine.[6]

DESCRIPTION OF SPECIES.

OSTRACODA.

Fam. LEPERDITIIDAE.

Genus Leperditia, Rouault.

Leperditia tatei, sp. nov. (Plate IX., Figs. 1*a*, *b*, 2*a*, *b*, 3*a*, *b*).

Description.—Carapace seen from the side nearly semicircular to suboval; height about two-thirds the length. Dorsal line straight or slightly curved; both extremities bluntly rounded, the anterior forming almost a right angle, bearing a flanged margin. Median

1 U.S. Geol. Surv., 10th Ann. Rep. (1888-9), 1890, p. 626, pl. lxxx., figs. 1, 1*a*.

2 Canadian Record of Science, vol. viii., 1902, p. 460.

3 Trans. R. Soc. S. Austr., vol. xv., 1892, p. 187.

4 Amer. Journ. Sci., ser. 3, vol. vi, 1873, p. 138.

5 U.S. Geol. Surv., Bull. No. 30, Second Contr. Camb. Faunas N. Amer., p. 146, pl. xvi., fig. 5.

6 Geol. Mag., Dec. 1 (n.s.), vol. x., July, 1903, pp. 303-304.

surface strongly convex; general surface punctate. There is an ocular spot in some specimens situated in the anterior third. Ventral view shows the characteristic infolded margin which in the left valve is overlapped by the right. The end view shows a sub-oval outline.

Dimensions.—Holotype,[1] length, 3 mm.; height, 2 mm.; thickness of carapace, 1 mm. Length of a paratype (Tate coll.), 4.4. mm. Length of another paratype (Sweet coll.), 2.4 mm.

Observations. —From the outline of the above fossil one is reminded of the Cambrian genus *Aluta*, especially *A.enyo*, Walcott sp.[2] The carapace in the South Australian species, however, is not continuously rimmed by a flange, and is not so uniformly compressed. This species is of the general form of *Leperditia anna*, Jones,[3] from the Calciferous Sandrock (Upper Cambrian) of St. Ann's, at the confluence of the Ottawa and St. Lawrence, Canada. L.tatei agrees in outline, position of the ocular spot, and the punctated shell-surface; *L.anna* differs from *L.tatei* in having a rounded, not margined, anterior, a more depressed and a larger carapace, the length of *L.anna* being 5 mm.

Leperditia tatei is evidently a very abundant form in the Curramulka Limestone, for fragments of the carapace are found scattered through it. In his paper on "The Cambrian Fossils of South Australia," Prof. Ralph Tate says[4] that the genus *Leperditia* "is indicated by the occurrence of two species, one, which has much resemblance to *L.dermatoides*, Walcott, is oval in outline, and about 3 mm. in the long diameter; the other has a circular outline with a diameter of about 1 mm. Both are moderately common, but I have not secured any example of either sufficiently free from matrix to permit of a critical comparison with figured species, or to figure with a sufficient degree of accuracy." The specimens referred to by Tate having been kindly lent me by Mr. Walter Howchin, I am in a position to say that the fossil mentioned as having a long diameter of 1 mm., is evidently that now figured as *Leperditia tatei* (paratype, pl. IX., fig. 2); whilst the larger specimen referred to as having an oval outline with much resemblance to *L.dermatoides*, Walcott is evidently a species of *Isochilina.*

Occurrence.—Grey Limestone. Upper Cambrian, Curramulka, S. Australia. Tate and Sweet colls.

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1 Pres. to National Museum coll.

2 *Bradoria enyo*, Walcott, Proc. U.S. Nat. Mus., vol. xxix., 1905, p. 99. *Aluta enyo*, Walcott sp., Research in China, vol. iii, 1913, p. 225, pl. xxiii., fig. 11.

3 Ann. Mag. Nat. Hist., ser. 3, vol. i., 1858, p. 247, pl. ix., fig. 18.

4 Trans. R. Soc. S. Austr., vol. xv, 1892, p. 187.

Leperditia capsella, sp. nov. (Plate IX., Figs. 4*a*, *b*).

Description.—Carapace seen from the side, broadly ovate, oblique. Hinge-line straight and thickened; about two-thirds the length of the carapace, anterior border almost at right angles to the back, with a slight re-entrant curve, obliquely rounded to the widely curved ventral edge; posterior extremity subangularly rounded and obliquely produced. Sides of carapace compressed, especially anteriorly and dorsally; highest part in the posterior third. Surface of valves finely punctate and crossed with fine linear markings parallel with the dorsal border. Muscle spot sub-central and slightly depressed, from which radiate fine striae. There is a well marked sub-median pit a litle below the thickened hinge-line. End view, acuminately ovate.

Dimensions.—Holotype; length, 3.9 mm.; greatest height, 3.05 mm.; thickness of carapace, 2 mm.

Observations.—The present species, *Leperditia capsella*, has many points of resemblance to *L.canadensis*, Rupert Jones,[1] another of the species found in the Calciferous Sandstone of Canada, and presumably of Upper Cambrian age. The more compressed form of the carapace, higher valves and stronger re-entrant curve of the anterior border, serving to distinguish our species, the outline of which reminds one of a seed-capsule of the common English weed, the Shepherd's Purse (*Capsella bursa-pastoris*).

Occurrence.—One specimen, left valve (Holotype), from the Sweet collection;[2] also a right valve, Tate collection, S. Australian Museum, lent by Mr. W. Howchin. From the grey limestone of Curramulka, S. Australia.

Genus **Isochilina**, Jones.

Isochilina sweeti, sp. nov. (Plate IX., Figs. 5*a*, *b*).

Description.—Carapace large, solid, strongly convex, highest about the centre. Seen from the side the valves are sub-circular, slightly oblique. Hinge-line straight, of moderate length, rather more than half the long diameter. Anterior border nearly at right angles to the hinge-line, rounded obliquely below to meet the widely-curved ventral border. Posterior extremity produced and well-rounded. Edges of valve bordered by a fairly wide flange, rounded

1 Ann. Mag. Nat. Hist., ser. 3, vol. i., 1858, p. 244, pl. ix., figs. 11-15.

2 Presented to the National Museum.

on the inner side and grooved on the outer. Valves equal. Surface smooth, with a muscle spot situated near the dorsal region of the anterior third, and a shallow depression (better seen in other unfigured specimens), near the dorsal area and slightly anterior to the middle.

Dimensions.—Length, 7.2 mm.; height, 6 mm.; thickness of carapace, 3.2 mm.

Observations.—Only one other species of this genus has been hitherto recorded from Cambrian beds, viz., *Isochilina ottawa*, Jones[1], which occurs in the Calciferous Sandstone of Canada, but which is also found in the Chazy Limestone (Arenig age). *I. ottawa* is only half the diameter of the present species, and is more oblong in shape.

From its contour one might at first be inclined to refer this species to *Aristozoe*, Barrande, but that genus is more compressed and pod-shaped, with nodular prominences in the antero-dorsal region. Moreover, it is less thickly calcified, as would be expected in a phyllocarid crustacean.

Occurrence.—This large and conspicuous species seems fairly common in the Curramulka Limestone. All the specimens examined were from the Sweet collection, with the exception of a doubtful, partially buried carapace from the Tate collection, S. Australian Museum (lent by Mr. W. Howchin, F.G.S.).

EXPLANATION OF PLATE IX.

Fig. 1.—*Leperditia tatei*, sp. nov.; *a*, right valve seen from the side; *b*, profile. Holotype. Sweet coll. × 10.

Fig. 2.—*L. tatei*, sp. nov.; *a*, left valve seen from the side; *b*, ventral edge view. Paratype. Tate coll. × 10.

Fig. 3.—*L. tatei*, sp. nov.; *a*, left valve of a narrower specimen; *b*, profile. Paratype. Sweet coll. × 5.

Fig. 4.—*Leperditia capsella*, sp. nov.; *a*, left valve seen from the side; *b*, profile. Holotype. Sweet coll. × 10.

Fig. 5.—*Isochilina sweeti*, sp. nov., *a*, right valve seen from the side; *b*, profile. Holotype. Sweet coll. × 5.

All the specimens are from the Upper Cambrian Limestone of Curramulka, South Australia.

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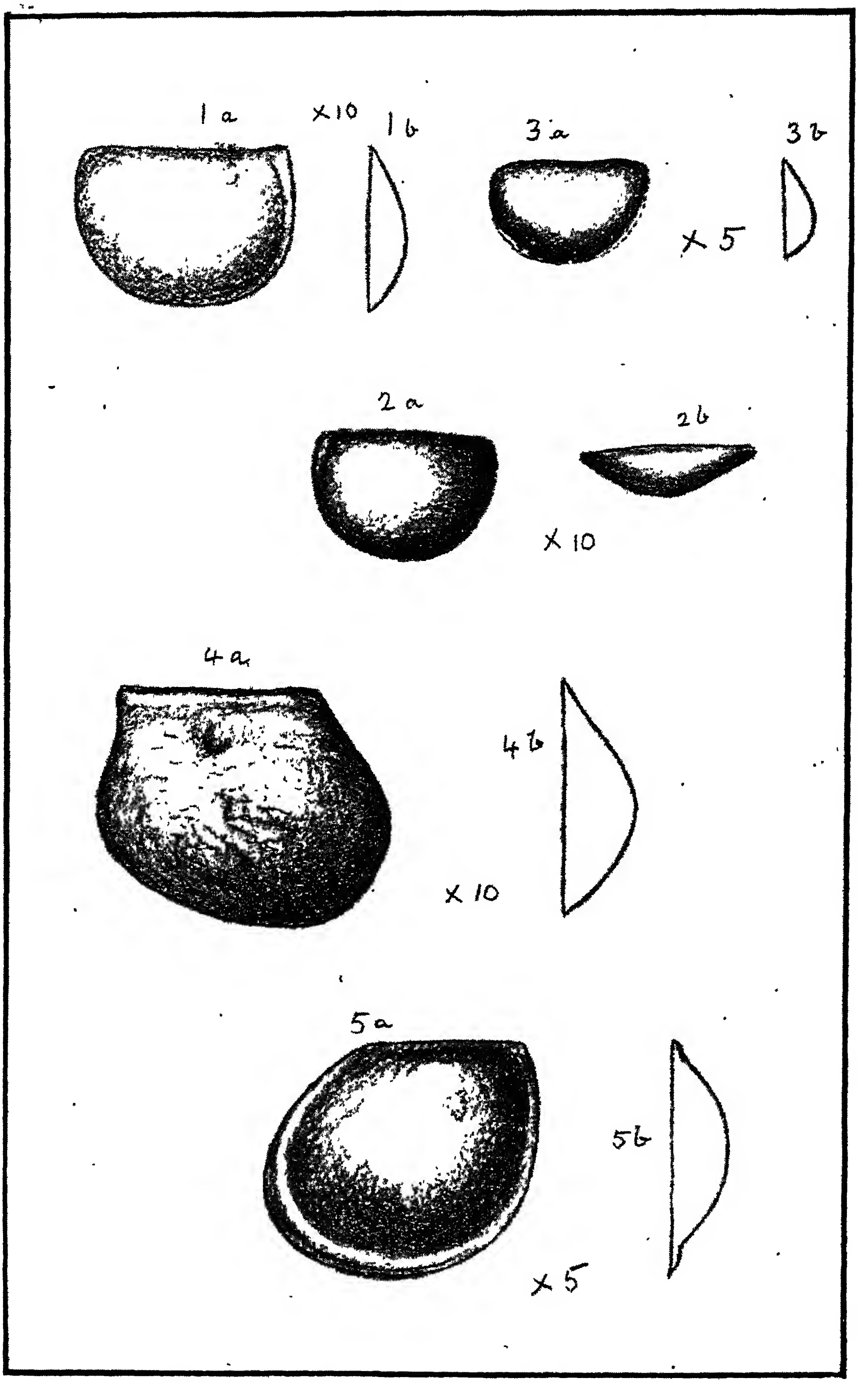
1 Ann. Mag. Nat. Hist., ser. 3, vol. i., 1858, p. 248, pl. x., figs. 1a-c. Geol. Surv. Can., Organic Remains, 1858, p. 97, pl. xi., figs. 14a-c. Ann. Mag. Nat. Hist., ser. 5, vol. xiv., 1884, p. 345.



F.C., ad. nat. del.

Upper Cambrian Ostracoda, S. Australia.

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART I., 1918].

ART. VI.—*The Sand Ridges, Rock Floors, and other Associated Features at Goongarrie in Sub-arid Western Australia; and their Relation to the Growth of Lake Goongarrie, a "Dry" Lake or Playa.*

BY J. T. JUTSON
(Geological Survey of Western Australia).

(With 3 full page illustrations).

[Read June 13th, 1918].[1]

Introduction.

Goongarrie is a small mining township fifty-five miles north of Kalgoorlie, on the railway from Kalgoorlie to Leonora. Its height above sea-level is 1277 ft., and it is situated on the Great Plaeau of Western Australia, where the climate is sub-arid and the rainfall slightly under ten inches per annum. The conditions therefore are not such as obtain under "normal" erosion; and as the topography appears to be unique and indicates to some extent the respective rôles of wind and water erosion in sub-arid Western Australia, this paper is submitted.

Summary.

The southern portion of Lake Goongarrie, a "dry" lake or playa, is described. It possesses dissected "high" lands, "lowlands," piedmont plains (some of which are truncated by low cliffs), rock cliffs, rock floors and small shallow rock basins on or towards its western side, with sands and silts on the eastern. In addition, there are small "islands" and "peninsulas," which are chiefly sand ridges, towards the western side. Between the sand ridges, which run approximately east and west, are narrow arms of the lake, which are rock-floored in their western portions, and tend to be silt-covered in their eastern portions.

Water action has cut the valleys in the hard rock of the "high" lands; it is mainly responsible for the "lowlands" by the cutting back (westward) of softer rocks; and also for the piedmont plains at the foot of the steep cliffs. The action of the rain has been

[1] By permission of the Acting Government Geologist of Western Australia.

largely or mainly responsible for the slow gravitative drift of detritus over the lowlands.

Portions of the lowlands have been changed by erosion into the rock- and silt-floored channel-like arms of the lake; and between the arms sand ridges have been built up. Detritus, due mainly to rain action and forming the continuation of the surface of the lowlands, underlies the sand ridges, but it has been entirely stripped off, and the bed-rock has been denuded, in the arms. The floors of such arms are not therefore merely "resurrected" surfaces; and they have probably been cut during the formation of the sand ridges.

The rock floors of the lake, its arms, the rock basins, the rock cliffs, and the low cliffs of the truncated piedmont plains are believed to be dominantly due to wind action.

The lake and probably the whole adjacent topographic system are regarded as migrating westwards, and the relations of the component parts of the system to one another are unique and without a known parallel elsewhere.

General Description of the District.

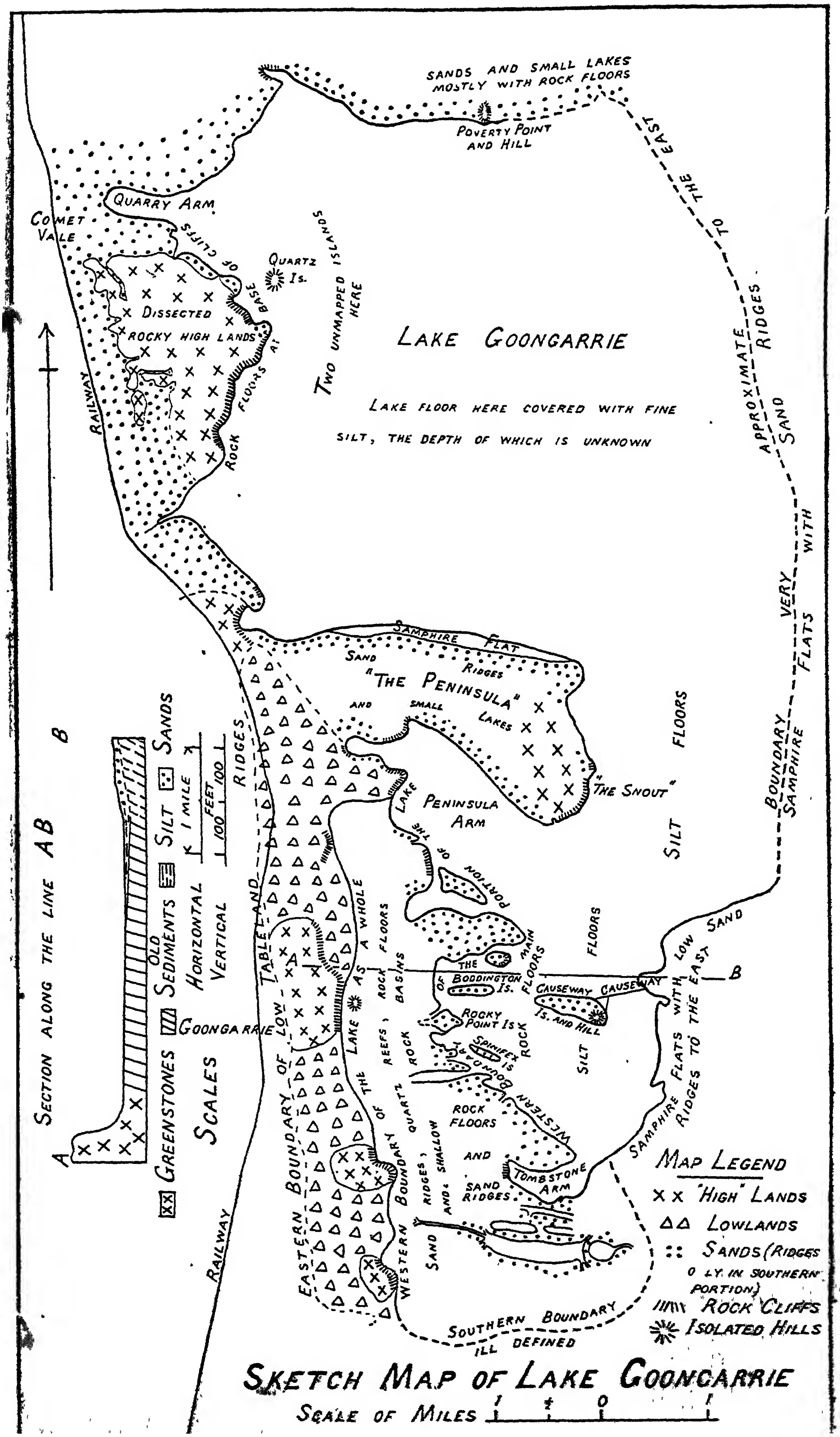
The main physical features are:—

(1) Three small belts of "high" lands consisting of hard resistant "greenstones," dissected by small early mature valleys, with a maximum depth of about 100 feet.

(2) The "lowlands," which consist chiefly of decomposed basic schists and form rather extensive areas (as compared with the "high" lands) of flat or gently sloping surface. They form with the "high" lands a north-north-west trending belt of country.

(3) The "dry" lake, or playa, known as Lake Goongarrie, which lies to the east of (and about 100 feet below) the township, and also to the east of the "high" lands and "lowlands," and of the mining township of Comet Vale, eight miles to the north. This playa is about eleven miles long in a north-south direction, with a greatest width from east to west of about six miles. It has rock cliffs and rock floors on the western and sands on the eastern side,[1] and, in addition, possesses (especially in the south-western portion) numerous islands, sand ridges, arms and quartz reefs and "blows." A long "peninsula" projects eastward between Comet Vale and

[1] The greater portion of the eastern side of the lake has not been traversed by the writer, but from the parts actually examined and from distant views, it is practically certain that the whole side has practically similar characters, that is, low sandy shores free from rock cliffs and rock floors.


SANDS AND SMALL LAKES MOSTLY WITH ROCK FLOORS
POVERTY POINT AND HILL
QUARRY ARM
COMET VALE
CLIFFS OF
QUARTZ IS.
TWO UNMAPPED ISLANDS HERE
DISSECTED ROCKY HIGH LANDS
BASE AT
ROCK FLOORS
RAILWAY
LAKE GOONGARRIE
LAKE FLOOR HERE COVERED WITH FINE SILT, THE DEPTH OF WHICH IS UNKNOWN
TO THE EAST
APPROXIMATE RIDGES
SAND
VERY
WITH
FLATS
BOUNDARY
SAMPHIRE
SAMPHIRE FLAT
SAND RIDGES
"THE PENINSULA"
AND SMALL LAKES
"THE SNOUT"
FLOORS
SILT
PENINSULA ARM
LAKE
THE
OF
PORTION
MAIN
FLOORS
THE BODDINGTON IS.
CAUSEWAY CAUSEWAY
IS. AND HILL
LOW SAND
WITH
RIDGES TO THE EAST
ROCKY POINT IS
SPINIFEX IS
ROCK
SILT
WESTERN BOUNDARY
ROCK FLOORS
AND
SAND RIDGES
TOMBSTONE ARM
SAMPHIRE FLATS
SOUTHERN BOUNDARY
ILL DEFINED
SECTION ALONG THE LINE AB
A
B
GREENSTONES
OLD SEDIMENTS
SILT
SANDS
GOONGARRIE
SCALES
HORIZONTAL 1 MILE
VERTICAL FEET 100 100
TABLE LAND
RIDGES
EASTERN BOUNDARY OF LOW
LAKE AS A WHOLE
THE REEFS, ROCK FLOORS
ROCK BASINS
WESTERN BOUNDARY OF QUARTZ
SAND RIDGES, AND SHALLOW
RAILWAY
MAP LEGEND
XX "HIGH" LANDS
ΔΔ LOWLANDS
SANDS (RIDGES ONLY IN SOUTHERN PORTION)
ROCK CLIFFS
ISOLATED HILLS
SKETCH MAP OF LAKE GOONGARRIE
SCALE OF MILES 1 ½ 0 1

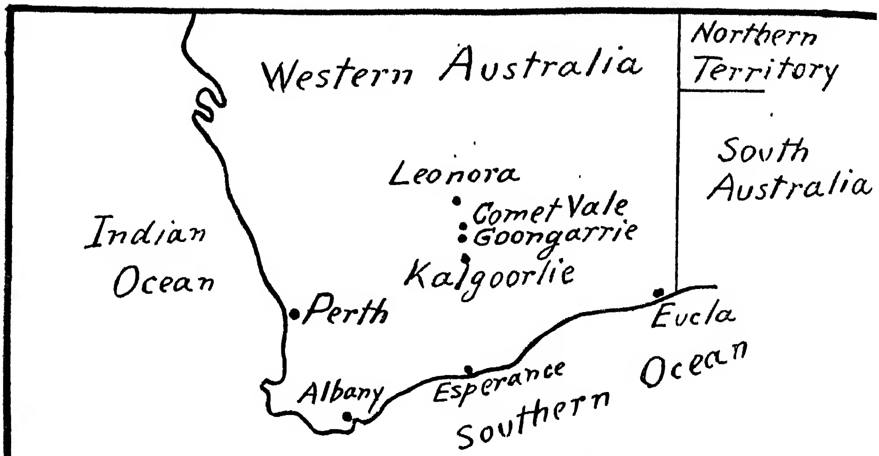


Fig. 1

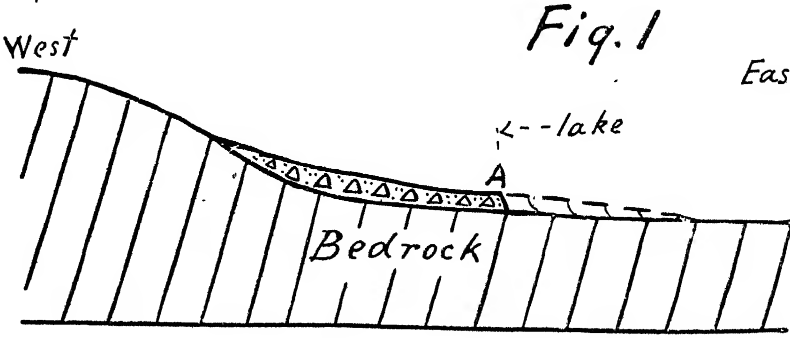
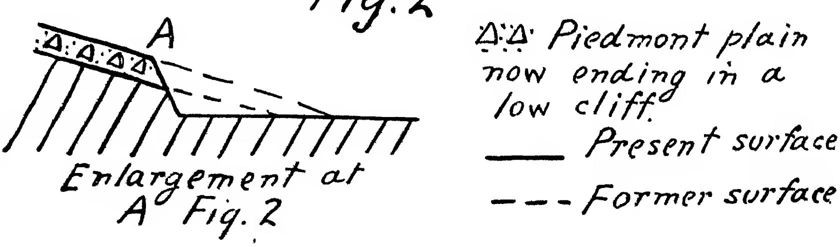


Fig. 2



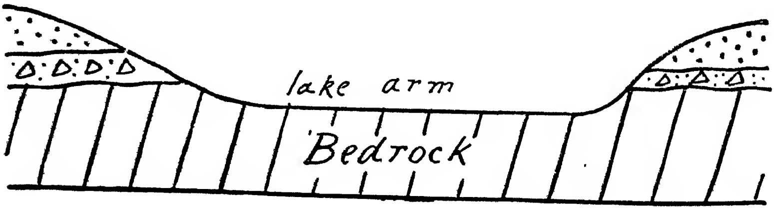


Fig. 3

"Wash" Blown sand.

about eight to thirty feet high, and, going westward, pass into mere embryonic ridges and thence into the surface deposits of the "lowlands." The regular ridges trend approximately east and west; are all fairly parallel to one another; have in some instances fairly steep sides, which may indicate scouring[1]; and form peninsulas and islands as well as bounding some almost closed arms of the lake.

The ridge sands consist of small and well rounded grains, chiefly of quartz and subordinately of ironstone. Gypsum occurs in and on the margin of the lake, but gypsum dunes have not been noticed, although they may possibly have been overlooked.[2]

The vegetation already described holds the sands to some extent, but the ridges can hardly be regarded as fixed.

The blown sands mostly do not rest directly on the bedrock, but overlie a detrital deposit from one to three feet or more thick, which consists of a mixture of fine clayey material, fine and coarse sand, and much detrital angular vein quartz, the fragments of which are usually under one inch in size. This deposit, which lies on the bedrock, is evidently due to water action and gravitional drift, and is no doubt the counterpart, and probably a continuation of, the third class of detrital deposits (other than sand ridges and lake silts) described above.

Rock floors, which in places are covered with white quartz detritus from adjacent reefs, or with a veneer of silt, bound the irregular ridges, and also at their western ends, the regular ones; but towards their eastern ends such regular ridges may be abutted upon by the lake silts, as well as by rock floors.

The Rock Cliffs, Rock Floors, and Rock Basins of the Lake.

The "lake" or "lake area," as here used, includes the lake as a whole; that is, the area where water may rest on bare floors (either of rock or of silt), although the surface may be broken by islands. The "main portion of the lake" is that part of the surface which is almost free from obstructions, and on which after heavy rain a practically continuous sheet of water might lie. Its outline is easily followed.

(1) *Rock Cliffs*.—The higher rock cliffs, composed of greenstones, occur along the eastern borders of the "high" lands, that is, the

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1 See Cornish, V. "On the Formation of Sand Dunes," Geog. Journ., ix. (1897), p. 288.

2 "Kopi" (powdered gypsum) occurs, but not as definite ridges.

western border of the lake, and there reach a height of about 100 feet.

The lower ones, composed of the altered sediments and porphyries, occur mostly along the western margin of the main portion of the lake. Both groups are receding westward.

(2) *Rock Floors.*—The rock floors may be divided into three groups, namely—(a) those of the main portion of the lake, (b) those of the arms of the lake between the regular sand ridges, and (c) those associated with the quartz reefs. The rock basins are separately described.

(a) The rock floors of the main portion of the lake occupy a considerable area of its western part, being traceable for a mile from west to east along a line just north of the Boddington Island. They are either almost wholly devoid of any detritus or possess a mere film, or a thickness of two or three inches of fine silt. In places they are slightly furrowed along the strike of the rocks, but this does not destroy the "billiard table" character of the floors.[1]

The actual plane of the surface may be slightly inclined or undulating, but precise levelling is needed to determine the directions of slope. So horizontal, however, are some of the rock surfaces that when rain falls (unless it be long continued) it simply rests on such surfaces without flow. This feature was observed by the writer in a part of the lake outside its main portion.

(b) The east-west trending arms of the lake associated with the regular sand ridges are rock-floored wholly or partly (except that a veneer of quartz debris from quartz reefs may lie upon them in places). Towards the eastern ends of the arms the rock floors are not always visible, as they may be buried under fine silt, which is believed to be nowhere in the arms more than a foot thick. The arms at their western ends in some instances break up into smaller irregular arms, which in places pass gradually into the "lowlands" previously referred to.

(c) The rock floors associated with the quartz reefs occur in the western portion of the lake, and mostly beyond the western boundary of the main portion of the lake. Although they may be regarded as portions of the lake, they yet form a number of more or less independent areas, owing to the occurrence of numerous and prominent quartz reefs which are from two to twenty feet high. These reefs, under exposure to the atmosphere, break up fairly rapidly, and consequently have a mass of debris around them which tends to cover

1 See Jutson, J. T., *Geog. Journ.*, December, 1917.

and protect the underlying rocks from erosion. Consequently, such rocks rise as hillocks with a central quartz reef. The uneven ground facilitates slight corrosion by water, and, in the lowest portions, deposition of fine silt a few inches thick. Where debris from different reefs meets, "stone fields," and to a less extent, "pavements," of white quartz result.

(3) *Rock Basins.*—True rock basins, by which are meant hollows with "live" rock surrounding them, are believed by the writer to occur in the lake floor, west of the main portion of the lake. The rocks are either decomposed porphyritic epidiorite or decomposed upturned sediments. These basins occur where the quartz reefs just referred to are so numerous. The basins are usually roughly circular or elliptical in shape; range in their longer diameters from 20 or 30 yards to 12 chains or more; and are so shallow (not being more than a few inches below the rock rim) that it is difficult by the eye alone to determine the difference of level.

The basins are occupied by fine aqueous silts a few inches thick; and after rain, water remains in the hollows and has no outlet, except where, as in some localities, an outlet appears to have been cut by water from an originally closed basin; and so one basin may connect with another by a shallow water channel.

The Silt Floors of the Lake.

Where the lake surface is not rock-floored, it is covered by a detrital deposit consisting usually of fine silt, composed chiefly of mud and subordinately of very fine sand. Taking the lake as a whole, by far the greater area is covered by silt, but to what depth is not known. This silt is usually of a dark red colour, owing to the contained oxide of iron, although the actual floor of the lake becomes white owing to the formation of a film of salt. No fossils have been found in the silts. The latter are, however, impregnated with common salt; and gypsum is abundant in the form of crystals from a quarter of an inch to four or five inches in length. The silts below the surface are practically always moist. Their thickness over most of the lake is not known, but towards the southern end bores showed that from where the rock floor ended at the western end of the Causeway Island to the eastern shore at the end of the Causeway, a distance of about a mile, the rock bottom sloped gradually to the east, until it was apparently about twelve feet below the lake surface at the eastern shore. Further information is desirable as to other portions of the lake, the portion tested by the bores being narrow compared with areas in the lake farther north.

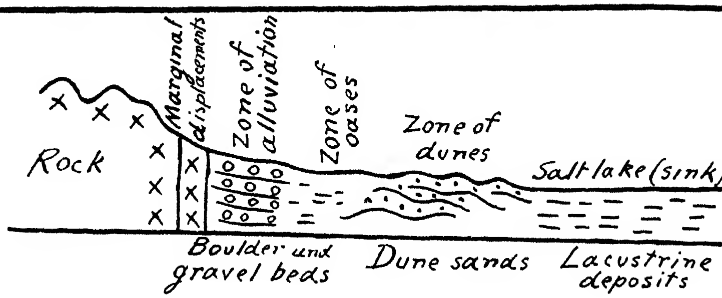

Fig. 4 (After Hobbs)

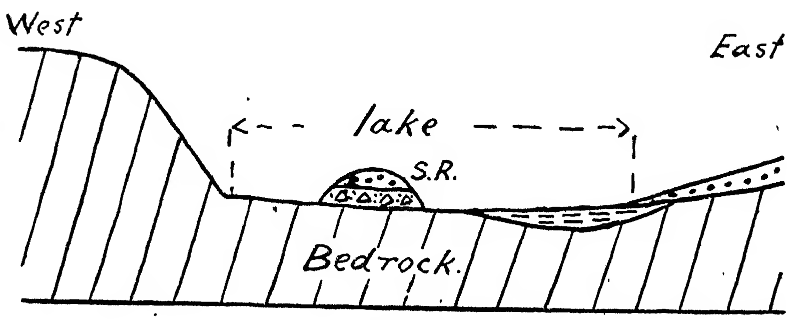

Fig. 5

∴ S.R. Sand dune overlying "wash" △△

Lake silts ∴ Sands of the eastern shore

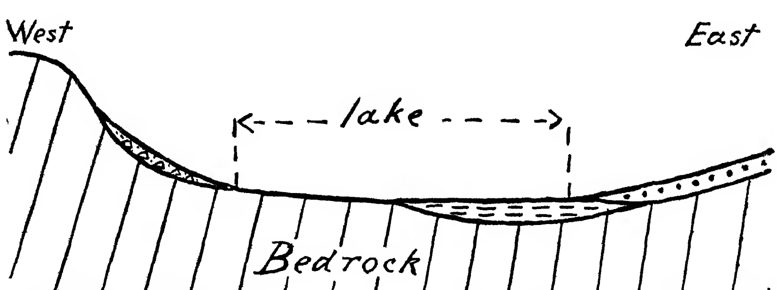

Fig. 6

△△ Detritus on lowlands

Lake silts ∴ Sands

Unique Characteristics of West Australian Playa Country as compared with other Areas.

So far as the writer's reading and observations extend, the features described above are quite unique, and nothing really similar has been found in any other part of the world. Elsewhere the general sequence from the high land to the playa surface across the various belts, is, according to Hobbs,[1] (1) the high land, (2) the zone of the dwindling river with its sloping bench of coarse rubble and gravel, (3) the belt of sand dunes which are often separated by narrow flat-bottomed basins carrying detritus, and (4) the central sink, which contains the true lacustrine deposits of clay and separated salts. There is no mention of bedrock floors here. Detrital deposits occur continuously from the foot of the high lands to the central sink.

At Goongarrie, proceeding from the high lands eastwards in a line just north of the Boddington Island across to the fine silts of the playa on its eastern side, the high lands of hard rocks terminate by fairly steep slopes or cliffs; thence follows a narrow piedmont plain made up of coarse detritus, brought down by the transitory streams, and having a gentle eastward fall; but such plain, instead of gradually sloping into flatter country, with a change to finer detritus, either ends abruptly in a low cliff (about four to six feet high) with a rock floor at its foot, or merges gradually into a rock floor. The piedmont plain is thus in the former case truncated. The rock floor extends eastwards for about one and three-quarter miles, broken only by quartz reefs and their detritus, by sand ridges, and by films of fine detritus in the rock basins or on the rock floors between the sand ridges. Farther east the fine silts cover the rock floor of the lake. In other places there is no piedmont plain, the high steep cliff being abutted by the rock floor. In others again the gently sloping "lowlands" take the place of the "high" lands. The sudden cessation of detritus and the occurrence of the bare rock floors are most striking, the rock floors possessing the appearance of having been recently swept by a gigantic broom.

1 Hobbs, W. H. "Earth Features and their Meaning," New York, 1912, pp. 216-217, and fig. 231.

Various Possibilities considered as to the Origin of certain of the described Features.[1]

The following remarks are offered with regard to the origin of the rock cliffs and the various rock floors described above.

(1) Fluviatile action seems to be incapable of producing these features. The normal results are as stated by Hobbs, but here the results are abnormal. In the longitudinal valleys of the high lands where the rain becomes far more concentrated and, consequently, has much stronger erosive power than have the waters on the lake (despite the presence of some vegetation in the valleys, and its absence on the lake), there are normal fluviatile deposits (coarse detritus and small flood plains a few feet thick). Hence, as this concentrated water cannot remove the detritus and produce rock floors in the valleys, it seems impossible to account for the rock floors of the lake by the action of diffused terrestial waters, the function of which on flat areas is, so far as known, to deposit detritus rather than to remove it.[2]

(2) Marine action could produce steep rock cliffs, but billiard-table floors are hardly to be expected in rocks of the character described; nor can marine action be considered as having produced the valley-like arms of the lake. Moreover, there is no evidence that the sea extended in recent geological times as far inland as the area described. No marine fossils have been found, and there is no occurrence of normal water-worn pebbles, such as would be expected if the cliffs were attacked by the sea.

(3) The erosive activity of former deep, permanent lakes might produce cliffs, but rock benches and true gravels would be expected, and these do not occur.

(4) The wind remains to be considered. It is accepted by the writer as the dominant agent of erosion. Its main activity is deflation, as the actual breaking or wearing down of the rocks is due to ordinary atmospheric weathering, the beating action of rain, insolation, "exsudation," and wind corrosion, but details cannot be given here. In the removal of the detritus from the foot of the cliffs, the lapping of the temporary lake waters no doubt in places assists.

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1 It is not proposed to deal with the origin of the lake as a whole. The "dry" lakes occupy drainage lines of the country, and therefore must be considered at least partly of fluviatile origin For the various theories of the origin of these lakes see the writings of H. P. Woodward, A Montgomery, C. G. Gibson, J. W. Gregory, and the present writer.

2 There are some ill-defined, very shallow water channels across portions of the lake floor west of the main portion of the lake, but they would not have sufficient fall or scour to keep the floors free from detritus.

Reasons for Acceptance of the Wind Theory.

(1) The elimination of other possible agents as shown above.

(2) The occurrence of rock cliffs and rock floors on the western side, and their absence on the eastern side of Lake Goongarrie and of numerous other "dry" lakes; the impossibility of explaining these features by the fluviatile, marine, or deep permanent lake theories; and the fact that such lakes appear to be migrating westward.

(3) The ignoring in the marine and deep permanent lake theories of the present erosinal processes.

(4) The passage of the piedmont plains into lower-lying bedrock floors, and the truncation in places of such piedmont plains into low cliffs.

(5) The occurrence of rock basins. Solutions appears to be the only alternative to wind erosion for these basins, and it does not seem to apply.

(6) The relations of the sand ridges, of the arms, and of the lowlands to one another.

Origin of the Rock Basins.

As true rock basins seem to exist, they can only have been produced either (a) by the wind in its deflative capacity acting on the products of unequal weathering or in its corrosive and deflative capacities, or by a combination of all three methods, or (b) by solution. There are no grounds for believing that solution is acting differentially, so that the wind in one of the three modes suggested is apparently responsible. The shallowness of the basins and their partial filling by fine aqueous silts (which are apparently due to rain), are in accord with the generalization enunciated by Passarge[1] and adopted by Davis,[2] as to the influence of rain in preventing the formation of deep wind hollows.

The Relations between the Sand Ridges, Lake Arms and "Lowlands."

The low cliffs forming the western boundary of the lowlands are furrowed and cut back by rain, and from their base ill-defined stream courses, a few feet wide and a foot or two deep, extend eastward down the gentle slopes which are covered by a layer, prob-

1 Zeit. der Deut. geol. Gesell., 56 Band, iv., Heft, 1904, p. 208.

2 Geographical Essays, p. 307.

ably not more than 18 in. thick as a rule, of fine and coarse detritus.

The occasional streams that traverse the lowlands become diffused and rapidly die out; they have not carried down the whole of the detritus. Probably most of such detritus has been transported by the slow drifting action of rain acting on the fine material, and by the slow gravitational drift of the coarser material.

As the detritus slowly travels down the slopes of the lowlands, much of the fine material is removed by wind and rain, and hence loose sands begin to accumulate, and are built by the wind into miniature ridges. Consequently, the bed-rock becomes exposed and surface drainage becomes more concentrated. Thus there is a distinct change from the detritus-covered slope, with practically no distinct water channels to the miniature sand ridges and rock-floored channels between. The miniature ridges grow into regular sand ridges, and the small channels grow into the largely rock-floored arms of the lake. In the area of the miniature ridges, and of the irregular sand ridges, water, once it is concentrated in definite channels owing to wind action, must remove some materials; but water action must almost fail in the more eastward areas, where the regular sand ridges occur, the rock-floored channels become pronounced arms, and the surface becomes lower; although portion of the quartz detritus that rests on the floors of the arms is probably carried there by rushes of water.

It therefore seems to the writer that the wind is mainly responsible for the arms as well as for the sand ridges, inasmuch as the wind apparently blows the detritus from the arm areas on to the parallel sand ridges, and in doing so, exposes the bed rocks, which in turn must be corraded to some extent by the blown sand as well as further disintegrated by ordinary weathering, the products of such weathering being carried away by the wind.

It might be argued that the longitudinal sand ridges are merely the remains of a one-extensive continuous sand-covered area, which has been eroded either by wind or water so as to form the lake arms. The sand of the ridges can, however, in any case, be explained only as wind-borne, and on the "lowlands" there are few sand ridges, such ridges being, in the area referred to, almost always associated with rock floors, so that the above supposition would not apparently hold good.

The dominant winds appear to be westerly. The sand ridges and lake arms are therefore approximately parallel to such direction and the ridges are longitudinal ones, with bare troughs

between. Cornish[1] regards longitudinal ridges as due to strong winds, and Free[2] also points out that they seem to occur where the supply of sand is small, relative to the strength of the wind. In the bare open lake arms the wind blows with great force, the difference of strength of the wind in the arms and on the sand ridges (which bear "mulga" vegetation) being very marked. As already shown, the blown sand of the ridges rests on detritus due to water action and gravitational drift, and this deposit, which is evidently identical with and a continuation of that of the "lowlands," in turn rests on the bedrock; hence the material has been available to assist in the formation of the sand ridges, and its removal from its original position has helped to form the rock-floored arms.

These rock floors, in almost every instance, rise as they approach the sand ridges; it is therefore reasonable to conclude that the rock floors of the arms are not merely "resurrected" areas, but that they have suffered erosion during the formation of the sand ridges. It might be objected that the sand ridges may have been in existence before the arms were formed, and that the two features are not necessarily connected, but in view of their constant association and of the transition from the lowlands to the sand ridges and arms, this objection has little or no validity.

In narrow arms the rock floor in cross section is distinctly, although but slightly, concave, and in the lowest portions a few inches of fine silt may occur. This silt has no doubt been laid down under quiet water. No flow of water was observed in any channel after moderately heavy rain, but after long continued rain a distinct flow would probably take place. The unfurrowed rock surface, and the very gentle slope to the east, together with the association of sand ridges and lake arms, however, forbid any serious erosion by water. It may be noted in this connection that as the channels or arms widen, the concave character of the arms in cross section usually becomes less and less until there is a level floor with gently rising edges at the sand ridges.

The rock-floored arms pass eastward into the rock floor of the main lake[3]; and at the eastern extremity of some of the sand ridges, as well as at the western end of some of the arms, low rock cliffs occur which are in process of reduction to a rock floor, the latter growing westward by such means. An example of this is shown at the eastern end of Rocky Point Island.

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1 Op. cit., pp. 292-293.

2 U.S. Dept. of Agriculture. Bureau of Soils. Bulletin No. 68 (1911), p. 65. See also Blake, Q.J.G.S., vol. 53 (1897), p. 229.

3 Some arms towards their eastern ends have floors of fine silt.

Where the "high" lands abut directly on to the lake, the sand ridges and arms may be unconnected with the "lowlands."

Westward Migration of the Whole Topographic System.

It would appear, therefore, that the "lowlands" originally extended farther east, but by the processes above described, strips have been removed to at least partly form the sand ridges, and, by such removal, the arms of the lake have been formed and the bed-rock planed down. The process is still apparently going on, the arms, and probably the sand ridges, extending westward, while bedrock at the eastern ends of the sand ridges is being planed to a level rock floor. The "lowlands" are being removed at their eastern side but the western side is extending westward by the wearing away of the low tableland and connecting cliffs. The heads of the drainage lines are cutting back westward, and such lines are being obliterated in their lower portions by the westward advance of the lake rock floors. As the latter grow westward the silt will tend to spread over them, hence the silt floors are probably extending westward, and they, in turn at their eastern margin, appear to be encroached upon by the sands.

Thus there seems to be a westward migration of practically the whole system, rock cliffs, rock floors, the lake itself (including the eastern and western shores), the lake arms, the sand ridges, the "lowlands," and the silt floors. If this conclusion be correct, it shows how portions of the country are being laterally planed away at a comparatively high level, and as wind is regarded as the governing factor, it also shows what an important part it is playing in the shaping of the land surface.

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART I., 1918].

ART. VII.—*The Significance of Lava Residuals in the Development of the Western Port and Port Phillip Drainage Systems.*

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(Field Assistant, Geological Survey of Victoria).

(With 10 illustrations in the text)

[Read June 13th, 1918].

This paper is the outcome of several years of observation in the drainage systems of Western Port and Port Philip. As it affords the most typical instances of that topographical form—the lava residual, the development of which is the subject of the paper—the Western Port area, where it is a conspicuous feature, has perhaps received more attention. The Yarra has been navigated from above Launching Place to its mouth, a journey of over a hundred miles, and there is perhaps no better way of demonstrating the truth of the axioms of physiography than to experience their effect. From Launching Place to the Warrandyte Gorge, the Yarra, except at a small gorge just below the confluence of the Watts and the Yering Gorge, meanders over a flood plain, and is comparatively sluggish.

The Beaconsfield, Berwick, Pakenham, Gembrook, Woori Yallock, Nar-nar-goon, Tynong and Drouin districts, afford the most suggestive physiography; generally the Western Port area seems to furnish the key to much that is inexplicable in the Port Phillip area.

In treating with such an extensive area, I have been prompted on the one hand by the inseparable relationship of the one system to the other, and on the other hand, by the desire of formulating a general scheme of classification before attempting more detailed observations on smaller areas.

I.—Introductory.

The residual and its physiographical significance.
Previous work.
Bass Strait lava field.
Pre Older Basalt cycle of Western Port and Port Phillip systems.
Western Port and Port Phillip lava fields.

II.—Evolution of a residual from a confined lava field.

Stages of evolution.
Relative resistance to erosion.
Short cycles of erosion during volcanic activity. Infilled lateral valleys.
Main lateral streams. Beginning of Intermediate cycle.
Minor laterals.
Process of breaching. Cross streams.
Residuals with resistant rocks on one side.
Ultimate configuration of residuals.
"Uncovered residuals."
Isolation of residuals.

III.—Evolution of a residual from an extensive lava field.

The western Newer Basalt lava field.
Development of a residual from an extensive lava field.
Junction of confined and extensive lava field. Cross lateral.
Significance of the cross lateral.

IV.—Distribution of residuals and classification of valleys.

Confines of two systems.
Residuals of Western Port system.
Residuals of Port Phillip system.
Systematic classification of valleys.

Synopsis of Paper.

Acknowledgments.

Bibliography.

The Lava Residual and its Physiographical Significance.

Lava residuals (Fig. 1). or those particular topographical forms known by such more or less inappropriate terms as "high level

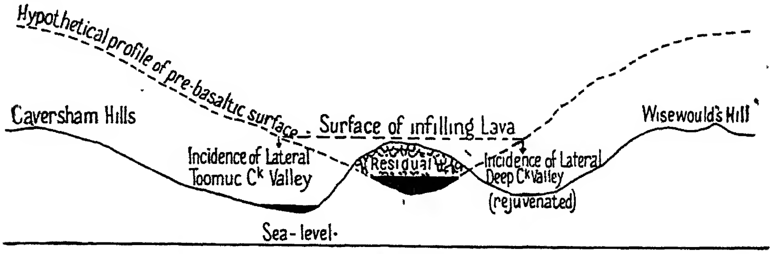

Fig. 1.

Section of a residual developed from a confined older Basalt lava field at Upper Pakenham.

leads," "high plains," or "volcanic plateaux," are the result of differential erosion—the greater resistance to erosion offered by basaltic lavas compared to the lesser resistance of the rocks contiguous to them. The development of a residual is characterised by three readily defined cycles of erosion. In the development of the Older Basalt lava residuals these cycles are as follows:—

(1) The Pre-Older Basalt Cycle, towards the close of which the stream system had reached a certain development (Fig. 3), with graded valleys probably for the most part of the mountain region type.

(2) The Older Basalt cycle extended over the period of volcanic activity during which the valleys of the previous cycle were occupied with lava for a considerable distance upstream, and a certain height above the pre-basalt stream. The lava confined between the pre-basalt watersheds of less resistant rocks, is referred to as a "confined lava field." At the locality down stream, where the lava overflowed these watersheds, an "extensive lava field" was formed. The period of volcanic activity was characterised by several short-lived and minor cycles of erosion at the conclusion of each flow, except that of the last one, which marked the beginning of the Intermediate cycle.

(3) The Intermediate Cycle inaugurated a new drainage system, for the lava of the second cycle had obliterated all traces of the previous drainage channels. The location of the new streams was guided by the position of the least resistant in regard to the more resistant rocks, and the direction of the gradient. Both of these conditions were fulfilled at the edges of the confined lava fields; consequently "lateral streams" (Fig. 1) started to cut back along these edges upward from the line of junction of the confined and extensive in lava fields.

Below this line of junction the new streams were compelled to carve out valleys on the resistant basaltic lava and assumed directions quite irrelevant to the submerged watersheds. The watersheds, however, being covered by the least thickness of lava, and, consequently, the lines of least resistance, were eventually exposed by vertical erosion. (Fig. 2.) Tributaries commenced to cut back

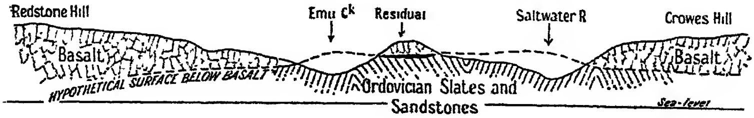

Fig. 2.

Section of a residual developed from an extensive lava field, north of Bulla.

along them and assisted by a system of domestic piracy, with comparative rapidity, became the main streams with the original streams as tributaries. These new streams thenceforth assumed the characterstics of lateral streams.

The widening of the lateral streams had the effect of gradually restricting the width of the residuals. Tributaries of lateral streams (termed "minor laterals"), having their source on and cutting back into a residual, tended ultimately to sever it into a number of isolated residuals, which became more and more isolated as the streams in question developed. A stream that has actually breached a residual is termed a "cross stream." During the Intermediate cycle the lateral streams, and their tributaries have been again and again rejuvenated by oscillation of the land surface, faulting and capture, and both lateral and cross streams have repeatedly deepened and widened their valleys. The Pre-Older Basalt stream levels are in many cases hundrds of feet above that of the neighbouring lateral streams, hence the use of the term "high level lead." Nearly all the residuals north of the railway from Melbourne to Drouin are conspicuous features, and many of the stream deposits or "leads" below them have been worked for gold.

To the west and north of Melbourne, however, the development of residuals from the Newer Basalt lavas is in progress. The valleys of the Intermediate cycle have been occupied or flooded by lava, and both confined and extensive lava fields have resulted. The development of these Newer Basalt residuals was likewise characterised by three cycles corresponding to the first, second, and third just mentioned, namely:—

(3) The Intermediate cycle just considered,

(4) The Newer Basalt cycle during which confined and extensive lava fields were formed in or above the lateral valleys of the Intermediate cycle, and

(5) The Post Newer Basalt cycle, at the beginning of which a new system of drainage was initiated, and is beginning to develop a system of lateral streams. Minor laterals are common, but as evidencing the fact that the development of the residual is in a youthful stage, it is significant that cross streams are correspondingly rare, in other words, the Newer Basalt residuals have only at few localities been breached.

Previous work.

The first notice of a lava residual seems to have been by Mr. R. A. F. Murray,[1] who, more than thirty years ago, described those at Dargo. He clearly recognised their physiographical significance, and commented on the condition of the ancient valleys immediately preceding the issue of the older lavas, indicating, among other interesting facts, the direction of the valleys. The sections illustrating the paper show the profiles of the pre-Older Basalt valleys.

Later, Messrs. S. B. Hunter,[2] A. M. Howitt,[3] and others, described and sectioned residuals in the north-east portion of Victoria, and showed them to possess characteristics in common with those at Dargo.

At a later date, Mr. Murray[4] sectioned the residual at Upper Pakenham, and indicated its bearing on the local physiography. This residual is typical of one evolved from a confined lava field, and from data that have since accumulated I have attempted another section.

At a still later date Prof. Gregory[5] sectioned the Kangaroo Ground residual.

From a physiographical standpoint, Mr. J. T. Jutson's several papers[6] cover much of the area dealt with in this paper; Prof. Gregory,[7] in a broad way, has treated on the whole of it; while Messrs. N. R. Junner,[8] T. S. Hart,[9] M. Morris, [10], and Dr. T. S. Hall,[11] and Dr. G. B. Pritchard[12] have from time to time commented on portions of it.

Reference will be made to these several contributions where the context requires it.

Bass Strait lava field.

The lava that partly occupied the ancient drainage systems of Western Port and Port Phillip is the northern fringe of a lava field that has for the most part been submerged by the waters of

1 Vide Bibliog., No. 16.
2 Ibid., No. 10.
3 Ibid., No. 9.
4 Ibid., No. 17.
5 Ibid., No. 4.
6 Ibid., No. 12 and 13.
7 Ibid., No. 4.
8 Ibid., No. 11.
9 Ibid., No. 7.
10 Ibid., No. 15
11 Ibid., No. 5.
12 Ibid., No. 19.

Bass Strait. The southern fringe is found at various localities on the north coast of Tasmania, its eastern fringe is probably in the vicinity of the partly submerged range between Wilson's Promontory and the north-east coast of Tasmania, and its extension westward is problematical.

As a necessary premise to the evolution of erosional forms on the mainland, it is assumed that Harker's[1] assertion relating to gradient, applied to the Bass Strait lava field. According to Harker, the surface of a lava stream has a certain inclination depending mainly on its viscosity and rapidity of cooling, but the actual gradient is very slight in the case of a stream of large volume. He quotes well-known examples from different parts of the world.

The eruption of Laki, on the south-west coast of Iceland, is an example within historic times, for in 1783 an old fissure re-opened for twenty miles and streams of basalt welled out from a number of new cones. The confluent lava streams formed floods which flowed over the surrounding country, and down two valleys —in one of which it travelled fifty miles, and was in places from twelve to fifteen miles in breadth, and eight hundred feet deep. The present volcanic activity of Iceland dates from the Eocene, and is supposed to be connected with the lava field of Antrim, which extended far within the Arctic circle. In Iceland it exceeds a thickness of 5000 feet.

The Columbia lavas of the United States are from two hundred to two hundred and fifty thousand square miles in extent, and have a maximum thickness of four thousand feet. The lava fields of the Deccan, Hawaii, Colorado and other areas may also be cited. An area in which the lava is in many respects in a similar stage of erosion to the Older and Newer Basalt lava residuals of Victoria is that the Uinkaret, described by Dutton[2] in his Monograph of the Grand Canyon district.

The Older basalts of Victoria[3] are assumed to have issued from eruptions mainly of the fissure type. Dykes and pipes have been found in various parts of the area by Messrs. Ferguson,[4] Chapman and Teale,[5] Ower,[6] and others. It matters little to the general

1 Vide Bibliog., No. 6.

2 Vide Bibliog., No. 2.

3 Prof. Skeats commented on the Tertiary basalts in his Presidential Address to the Brisbane Meeting of the Australasian Association for the Advancement of Science for 1909. Bibliog., No. 20.

4 Bibliog., No. 3.

5 Ibid., No. 1.

6 Ibid., No. 18.

conclusions arrived at in this paper how the lava was extravasated, or whether the crustal movements responsible for it were of the mountain or plateau building types. What is more important from the standpoint of the physiographer and palaeographer is to reconstruct the lava field as it was at the cessation of volcanic activity, and only volcanic phenomena essential to this reconstruction are considered. The Older and New Basalt residuals afford, it is submitted, the necessary data for this reconstruction.

Pre-Older Basalt cycles of Western Port and Port Phillip.

Portion of the Western Port system during the Pre-Older Basalt cycle was, as it is now, a mountain region. The same factors that made it so then are in operation now, namely, highly resistant metamorphic rocks at the contact of Palaeozoic granitic and

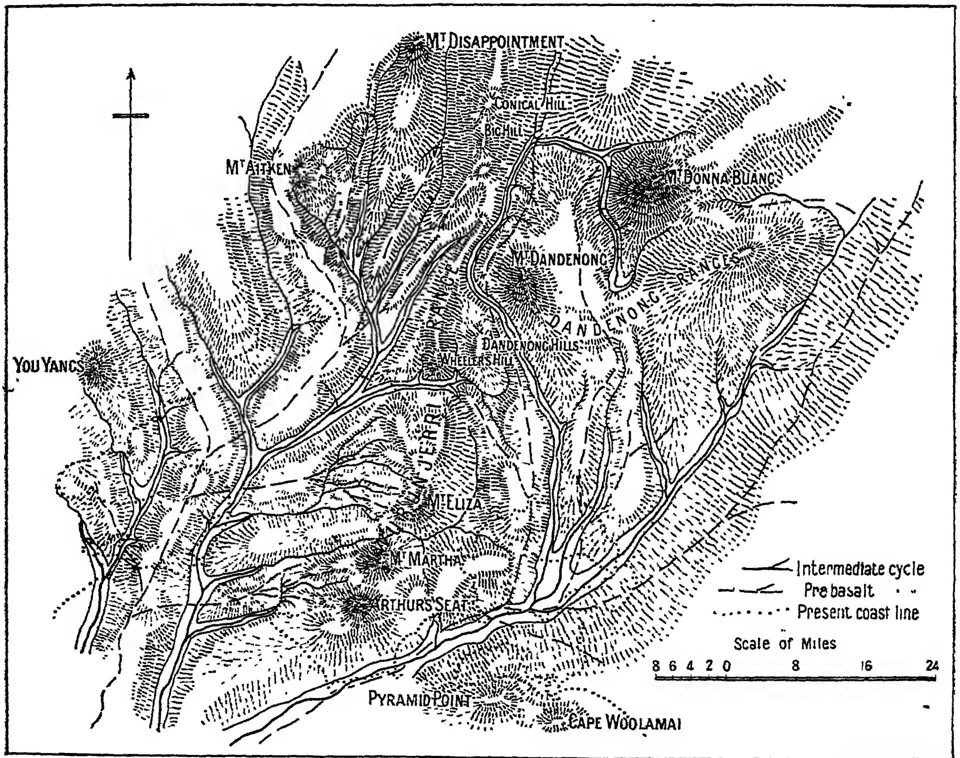

Fig. 3.

New basalt valleys of pre basalt cycle. These valleys were infilled with the older basalt which precipitated the intermediate cycle.

sedimentary series, and massifs of almost equally resistant dacite, also of Palaeozoic age. The Older Basalt and Newer Basalt are of Tertiary age.

If the large stream[1] that flowed in the vicinity of Klingsporn's Station,[2] Wood's Point, Mt. Leckie, Drouin, Lang Lang, French Island, Flinders and Cape Shanck had its source at Mount Buller and its outlet somewhere near Flinders Island in Bass Strait, as the bathymetrical contours would suggest, only its headwaters are represented in the 130 miles now above sea level. The most mountainous part of its course was between Mt. Buller and Drouin, and in the vicinity of Flinders. Bearing in mind that the mature erosion of a mountain region, which a reconstruction of the residuals appears to suggest, is characterised by steep declivities rising sometimes thousands of feet above the flood plain, one may comprehend much that seems unusual from the two thousand feet of lava assumed to have existed at Flinders from the evidence of a bore, and the amount of denudation disclosed by the slope above it. Perhaps the valleys of the Kiewa, Buckland, and other streams in the north-east province of Victoria are comparable to the Pre-Older Basalt stream just mentioned; they are typical examples of erosion in a mountain region; and meander over well graded flood plains.

The erosion of the Port Phillip system during the Pre-Older Basalt cycle was affected by different considerations. There were no dacite massifs, and the contact metamorphic rocks were so disposed that large areas of the less resistant rocks permitted a rapid development of the stream system.

Western Port and Port Phillip lava fields.

With data forthcoming from the sections of residuals (Fig. 4), their configuration (Fig. 9), disposition, and the trend of "uncovered residuals,"[3] a reconstruction of the surface of the Western Port and Port Phillip lava fields is possible. This reconstruction (Fig. 4) shows that at the cessation of volcanic activity the valleys of the Pre-Older Basalt cycle were occupied in their upper portions by long tongues of lava (confined lava fields), which merged southwards into a more extensive plain (extensive lava field). South of

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1 Ostensibly, Prof. Gregory's Tarago, vide Bibliog., No. 4.

2 Klingsporn's Station is situated south-west of Mount Buller, between the Howqua and Jamieson Rivers. The area of older Basalt representing the residual has never been charted.

3 Vide p. 147, post et fig. 8.

	PORT PHILLIP SYSTEM.				WESTERN PORT SYSTEM.									
	Spotswood.		Mordialloc.		Lang Lang.		Corinella.		Phillip Is.		Flinders		Cape Schanck.	
Post Newer Basalt Cycle														
New Basalt Cycle	Basalt	29.0	Clays and sands	223.0	Clays, sand and drift	4	Sand and clays	330.6	Sands and clays	12.0	Surface soil dark	1.0	Surface sand and clay	9.6
Intermediate Cycle	Blue calcareous and lignitiferous clays	141.0									Clay, yellow	20.6	Basalt rubble and boulders	6.0
Older Basalt Cycle	Basalt Basaltic clay and ash	83.3 6.9	Basalt	17.0	Basalt, more or less decomposed Basalt, hard and dense Basalt, vesicular Lignitiferous sands, clays and drifts Basalt, hard		Basalt	47.6	Basaltic clay Basalt, hard Clay, basaltic Basalt	69.9 71.6 9.6 23.9	Basalt decomposed Basalt hard, jointy, with decomposed layers Clay basaltic Basalt, hard, broken Basalt decomposed and balsaltic clays	112.0 843.0 176.0 20.6 127.0	Basalt, concretionary hard Basalt decomposed Basalt, portions dense, portions decomposed Basalt gravel and conglomerate Clay, basaltic red and grey Basalt crushed and broken in places Clay and decomposed basalt, glicken sided in places Basalt	18.0 63.6 271.9 8.9 187.0 178.6 69.0 48.0
Pre Older Basalt Cycle	Clay Sand, with pebbles and lignitiferous material Sand and large pebbles	14.0 22.0 26.6			Lignitiferous clays and drift	166.	Sands and clays	68.0						
Palaeozoic or Mesozoic		7.6						536.0		169.0				
Total depth bored		330.0		240.0				982.0		356.0		1300.0		860.0

a line, represented approximately by the railway line between Melbourne and Drouin, this extensive lava field was more than thirty miles wide, but converged towards Flinders, and passed through the bottle-neck there on to the now submerged area of Bass Strait. The confluence of the confined and extensive lava fields approximately in the vicinity of the railway line, marked a change in gradient due in the first place to lava streams being confined within the comparatively narrow limits of the valleys, and in the second, to the lava rising above the watersheds and flooding an extensive area.

So much of the Port Phillip lava field is buried beneath the Upper Tertiary lavas and sedimentary deposits, or submerged under the waters of Port Phillip Bay, that the evidence for reconstructing it is less direct than that of the Western Port area. The sections available seem to indicate that the several tributaries joined the trunk stream at more regular intervals than those of the Western Port system, and as a consequence the valleys were more evenly graded. That a considerable volume of lava poured down the main valleys is evident from the thickness still existing in the vicinity of Essendon and Bellarine. It probably first began to flood the watersheds in the vicinity of the railway line between Melbourne and Drouin. Older volcanic lavas were pierced by bores at Mordialloc and Frankston.

From considerations of viscosity and cooling, it is obvious that lava flows confined to valleys and regulated as the Western Port flows were by a single outlet, are relatively thick compared to those that have welled out and flowed over a plain surface, as the lava did once the pre-existing watersheds were flooded, and an extensive lava field was formed. The implication is that wherever the valleys were restricted the lava was to some extent banked up, resulting in a greater thickness and extent of lava at and upstream from the bottle-neck. Such a circumstance is implied by the Flinders and Gembrook bottle-necks; the accumulation of lava at these localities has had a profound effect on the subsequent development of the streams of the Intermediate cycle by retarding it, and in the case of the streams above the Gembrook bottle-neck, reversing their direction. Bottle-necks undoubtedly marked a great change in the gradients of the lava fields.

The gradient was materially affected by the proximity of a vent or fissure to the valley. Prof. Skeats suggests[1] that if a vent or

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1 Verb. cit.

fissure opened in or across the valley, a portion of the lava may have found its way up the valley, in which case the point of issue would also mark a change in the gradient of the lava fields. There seems to be evidence of this to the north of Gembrook.

The following is a tabulation of the strata passed through by several bores put down by the Mines Department. The correlation of the strata into their respective cycles is my own.

"High level leads," or the beds of streams belonging to the Pre-Older Basalt cycle, have been worked for gold at Gembrook, Hoddle's Creek, Wandin, Upper Pakenham, Neerim, Mt. Leckie, Lilydale and numerous other localities. The Quarterly Reports of the Mining Registrars for the first and second decades after the discovery of gold in Victoria, contain many references to these "high level leads," and the difficulties encountered in working them. The main difficulty was what is termed by miners "loss of level," due to an inadequate conception of the depth of the valleys and their trend; they often failed to tunnel into the lead at a sufficient depth to get under it, a necessary procedure to ensure efficient drainage.

At Wilson's Quarry, in the Berwick residual, there is a thickness of about seventy feet of lava. In the floor of the quarry leaf beds are exposed, below which again is the bed of an old stream belonging to the Pre-Older Basalt cycle. This old stream undoubtedly rests on Palaeozoic slates and sandstones, which are exposed in the quarry.

Alternating steep and gentle slopes of certain residuals suggest the intercalation of softer strata, but if these softer beds were numerous or of appreciable thickness, sections of residuals would correspond to the mesas of the Grand Canyon district of Colorado,[2] to which they bear little resemblance.

A survey of the evidence derived from borings and sections seems to permit of the following inferences :—

(a) That from the outbreak to the cessation of the Older Volcanic activity there were periods of quiescence indicated by intercalated clays and sands.

(b) That compared to the subsequent erosion, and accumulation of sediments in the lateral valleys, these periods of quiescence were of short duration.

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1 Vide Bibliog., No. 14.

2 Vide Bibliog., No. 2. "The Uinkaret."

It is not known, however, whether the clays between the lava flows were residual[1] or transported, or whether they represent the whole or only part of them. These and other pertinent considerations arise, but the inference seems tolerably safe that the period of volcanic activity was comparatively short compared with that of the Intermediate cycle between the Older and Newer Basalt. From such a point of view these phases of volcanic activity are of great stratigraphical and physiographical value, marking, as they do, the termination and inception of three great cycles of erosion —the Pre-Older Basalt, the Intermediate, and the Post Newer Basalt.

Some stress has been placed on the use of such terms as "older basalt" and "lower newer basalt," but I venture to think, especially as the same flow is designated by both symbols, that only one period is meant. The use of the two symbols has probably arisen from the points of view of the two observers, one of whom considered it to belong to the close of the Miocene and the other to the beginning to the Pliocene.

Mr. Jutson[2] thinks that there is some reason, on lithological grounds, for establishing an intermediate period of volcanic activity. The complications arising from the assumption of an intermediate flow are referred to in another part[3] of this paper.

II.—Evolution of a Residual from a Confined Lava Field.

Stages of Evolution.

At the beginning of the Intermediate cycle the valleys towards their headwaters contained long and narrow lava fields flanked by watersheds of less resistant rocks. The streams of the two previous cycles were submerged beneath the Older Basalt so that the drainage of the Intermediate cycle was forced to seek new outlets. The development of the new drainage system was guided by two factors, namely, the direction of highest gradient, and the line of least resistance, conditions that were at once fulfilled by the comparatively unresistant rocks at one or both edges of the lava.

The resistance of the rocks flanking a residual affords a means of classifying them. They severally belong to one of the following stages :—

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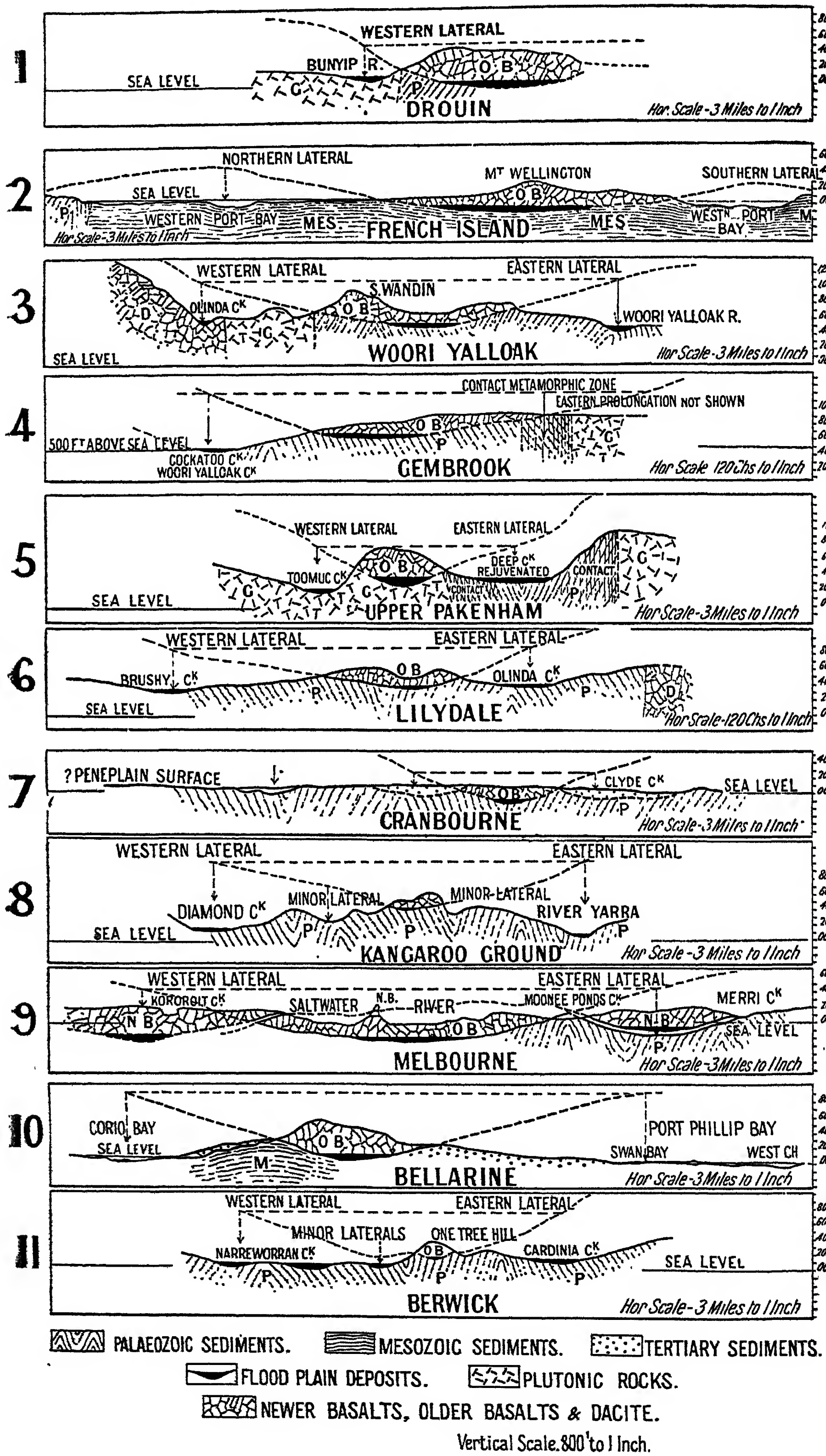
1 Mr. Ower, Assistant Boring Engineer of the Geological Staff, assures me that the intercalated clays in the Flinders and Cape Schanck bores were residual.

2 Vide Bibliog., No. 13.

3 Vide p. 143, post.


1
WESTERN LATERAL
BUNYIP R.
SEA LEVEL
O B
G
P
DROUIN
Hor. Scale-3 Miles to I Inch
2
NORTHERN LATERAL
MT WELLINGTON
SOUTHERN LATERAL
SEA LEVEL
O B
P
WESTERN PORT BAY
MES.
FRENCH ISLAND
MES
WESTN. PORT BAY
M
Hor Scale-3 Miles to I Inch
3
WESTERN LATERAL
EASTERN LATERAL
S.WANDIN
OLINDA CK
D
O B
G
WOORI YALLOAK R.
SEA LEVEL
WOORI YALLOAK
Hor Scale-3 Miles to I Inch
4
CONTACT METAMORPHIC ZONE
EASTERN PROLONGATION NOT SHOWN
500 FT ABOVE SEA LEVEL
O B
P
C
COCKATOO CK
WOORI YALLOAK CK
GEMBROOK
Hor Scale 120 Chs to I Inch
5
WESTERN LATERAL
EASTERN LATERAL
DEEP CK REJUVENATED
CONTACT
TOOMUC CK
O B
G
SEA LEVEL
UPPER PAKENHAM
Hor Scale-3 Miles to I Inch
6
WESTERN LATERAL
EASTERN LATERAL
BRUSHY CK
O B
OLINDA CK
R
P
D
SEA LEVEL
LILYDALE
Hor Scale-120 Chs to I Inch
7
? PENEPLAIN SURFACE
CLYDE CK
SEA LEVEL
O B
P
CRANBOURNE
Hor Scale-3 Miles to I Inch
8
WESTERN LATERAL
EASTERN LATERAL
MINOR LATERAL
MINOR LATERAL
DIAMOND CK
RIVER YARRA
SEA LEVEL
P
KANGAROO GROUND
Hor Scale-3 Miles to I Inch
9
WESTERN LATERAL
EASTERN LATERAL
KORORoIT CK
SALTWATER
N.B.
RIVER
MOONEE PONDS CK
MERRI CK
N B
O B
SEA LEVEL
P
MELBOURNE
Hor Scale-3 Miles to I Inch
10
CORIO BAY
SEA LEVEL
O B
M
PORT PHILLIP BAY
SWAN BAY
WEST CH
BELLARINE
Hor Scale-3 Miles to I Inch
11
WESTERN LATERAL
EASTERN LATERAL
MINOR LATERALS
ONE TREE HILL
NARREWORRAN CK
O B
CARDINIA CK
SEA LEVEL
P
BERWICK
Hor Scale-3 Miles to I Inch
PALAEOZOIC SEDIMENTS.
MESOZOIC SEDIMENTS.
TERTIARY SEDIMENTS.
FLOOD PLAIN DEPOSITS.
PLUTONIC ROCKS.
NEWER BASALTS, OLDER BASALTS & DACITE.
Vertical Scale 800' to I Inch.

(a) Residuals due to the erosion of rocks of varying resistance flanking the protective lava beds, the rocks on one flank being a little more resistant than the lava. One lateral valley has formed, as in the Gembrook residual (Fig. 4[4]), but the other will subsequently form, or is in process of formation, as in the Woori Yallock residual (Fig. 4[3]).

(b) Residuals where the flanking rocks are more resistant on one side, but somewhat less resistant than the lava. Erosion is facilitated on one side and retarded on the other; consequently one lateral valley approaches maturity more rapidly than the other. The Upper Pakenham and Lilydale residuals are examples (Fig. 4[5 & 6]).

(c) Residuals due to the erosion of relatively feebly resistant rocks flanking the hard lava. If the flanking rocks are of relatively uniform resistance the lateral valleys are of equal importance. The Berwick residual is typical of this stage. (Fig. 4.[11]).

From the fact that the resistance of the flanking rocks is always variable, even in the case of a residual developed under the conditions outlined for stage (c), all pass successively through the above development stages. Concisely the three stages may be taken to represent the orderly evolution of a residual from a confined lava field, and are successive stages in the process of denudation, the object of which is to reduce the lateral streams to base level, and, incidentally, remove by lateral planation the lava protection.

Relative Resistance to Erosion.

In descending order of decreasing resistance to erosion, the rocks of the Western Port and Port Phillip areas may be tabulated as follows:—

Firstly—Metamorphic rocks at their actual contact with igneous rocks of Palaeozoic age.

Secondly—Volcanic rocks.

(a) Dacite, andesite, etc., of Palaeozoic age.

(b) Lavas of the Newer Basalt.

(c) Lavas of the Older Basalt.

Thirdly—Plutonic rocks.

Granites, granodiorites, syenites, etc., of Palaeozoic age.

Fourthly—Sedimentary rocks.

(a) Palaeozoic sandstones shales and slates.

(b) Jurassic sandstones and shales.

(c) Tertiary sediments.

(d) Decomposed igneous rocks, particularly the lavas of the Older Basalt.

It will be recognised that the structure and physical characteristics of these several rocks modify their powers of resistance. The metamorphic rocks, placed above as the most resistant, merge into one of the least resistant at a variable distance from the actual contact; they retain more or less of their tectonic structure, and in this respect are subject to the same erosional factors as their unaltered representatives. Igneous rocks decrease in resistance according to whether they are vitreous, hypocrystalline or holocrystalline. The marked difference in resistance between those secondly and thirdly tabulated seems to be due to this rather than to any decided dissimilarity in chemical composition. The Palaeozoic sediments as a whole offer little resistance compared to the igneous rocks, but their sandstone members are sometimes more resistant than some igneous rocks.

Short cycles of erosion during Volcanic activity.

Short cycles of erosion were initiated at the beginning of the comparatively brief periods of quiescence between the lava flows comprising the Older Basalt, and lateral streams commenced to cut back from the changes of gradient at the edge of the confined lava fields. Erosion had not proceeded to any extent before another lava flow filled in the young valley, and a new cycle commenced at the edge of the last flow. Infilling and erosion thus proceeded hand in hand until a cycle of erosion—the Intermediate—proceeded uninterrupted. The inferences arising from this sequence of events is both interesting and important. A section (Fig. 5) will better illustrate the possibilities arising from it.

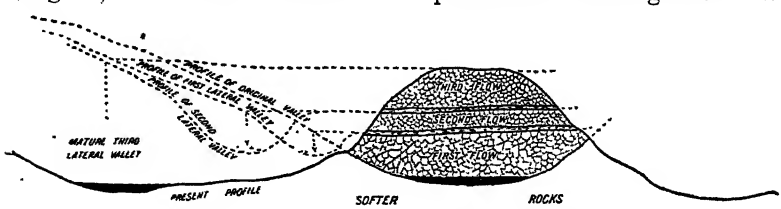


Fig. 5.

Erosion succeeding three consecutive lava flows with a comparatively short space of time between them. Hypothetical Section.

Fig. 5 shows the erosion succeeding three consecutive lava flows with a comparatively short period between them. The same amount of lava is supposed to be represented by each flow. Note the "turtle shape" (to use Dutton's[1] term) of the residual.

Now let us suppose that another series of lava flows has welled out and occupied graded lateral valleys initiated at the close of the Older Basalt. This is so as regards the Melbourne residual (Fig. 49), where the Newer Basalt has occupied valleys belonging to the Intermediate cycle and initiated a new cycle—the Post Basalt cycle. This new cycle has proceeded on the same lines as the Intermediate cycle and lateral streams, namely the Merri and Moonee Ponds Creeks, have been formed at the edges of the confined Newer Basalt field. The western edge of the residual is flanked by the Newer Basalt extensive lava field, and the Saltwater River is in the unique position of being a lateral to an extensive lava field formed on the little resistant decomposed lava of the Older Basalt.

If an intermediate phase of volcanic activity had occurred the Newer Basalt instead of occupying the lateral valleys of the Older Basalt residuals, would be occupying the lateral valleys of this supposed intermediate lava, and a complicated system of erosion would have resulted at the inception of the Newer Basalt cycle.

Main lateral streams. Beginning of the Intermediate cycle.

Erosion commenced simultaneously on the softer rocks flanking the confined lava field and on the lava field itself. The resistance of the latter, however, soon threw (Fig. 6) the incidence of erosion on to the less resistant flanking rocks, where it will remain until the residual disappears by lateral planation. The streams that formed on the lava field were quickly captured by the lateral streams on the less resistant rocks; the indented configuration, exhibited by many residuals in plan, is due to the cutting back of these captured streams. Until the lateral streams assumed a mature aspect, the talus boulders broken away from the lava by sapping had a powerful abrasive effect in corrading and gouging out the lateral valleys. As, however, the talus slopes became graded, much of their force was expended on the reduced talus slope. Talus boulders may be seen at the edge of the lava at Harkaway where, from large angular ones at the edge and smaller subangular ones down the slope, they ultimately become small and rounded still further away.

1 Vide Bibliog., No. 2.

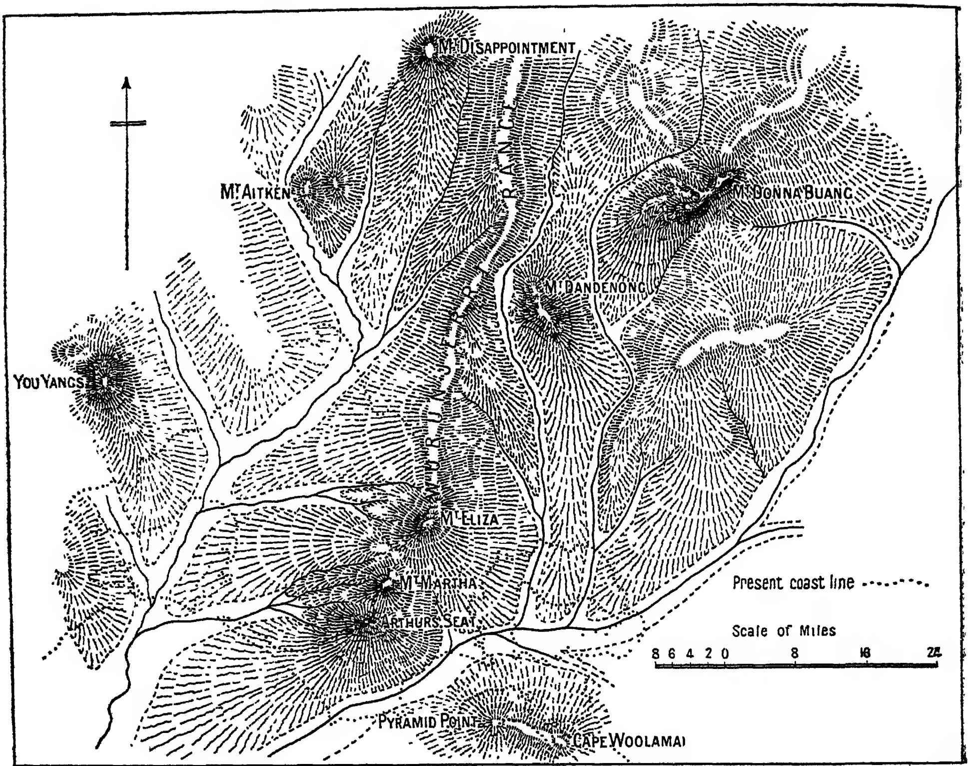


Fig. 6.

A stage in the development of the intermediate cycle some time after the cessation of volcanic activity. Note that the pre basalt streams are on the watersheds (infilled valleys) between the streams of the intermediate cycle.

The rate of cutting back of the lateral streams was regulated, in the first place, by the extensive lava field to the south, over which all streams had to pass, and, in the second case, by infilled tributaries which formed smaller confined lava fields at an angle to the main field, at irregular intervals throughout its length. A stream cutting back and encountering an infilled tributary worked along the tributary lava field until by vertical erosion and sapping the tributary lava field was breached; this usually occurred at or near the main confined lava field.

It is not to be assumed that lateral streams did not immediately form along the whole length of the main infilled valley. They existed from the first as streams of steep and variable gradients,

broken with falls, rapids, and shallows, particularly where the tributary confined lava fields joined the main confined lava field.

The added force to the main lateral, once an infilled tributary had been breached, was considerable, and accelerated breaching further back. The breach soon widened, and the detached tributary field became more and more isolated. Many detached and isolated residuals of small dimensions have had the relation of an infilled tributary to the main confined lava field. The best examples are to be found to the east of Pakenham and the north of Gembrook. They have not, as far as I am aware, any particular names.

Where a tributary of relative importance joined the main stream, particularly towards its head waters, the lateral streams on the outer edges of the lava became the main laterals, and those on the inner edge were suppressed or became tributaries. (Fig. 7.) This has probably occurred in the vicinity of Broadmeadows, where two Pre-Older Basalt streams had their confluence, one from the direction of Romsey and the other from Wallan.

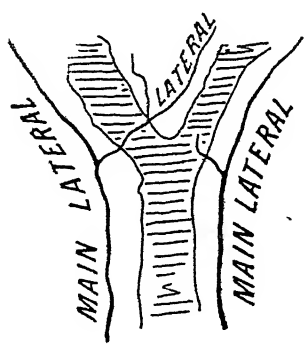


Fig. 7.

Lateral valleys at the confluence of infilled valleys.

Minor laterals.

The erosion of minor laterals on the talus slope between the main lateral and the receding edge of the lava is an important and characteristic feature. They commence when and where the talus slope has assumed such a low gradient that underground and meteoric waters cut in a diagonal direction across it; they are particularly apt to form where the residual is altering its general trend, and have a tendency to attack the residual on both its con-

cave and convex sides. The cutting back of a minor lateral is materially assisted by the talus boulders, which accumulate in the slightest runnel and particularly on the step or flat at the edge of the lava. This step or flat is a noticeable feature near all residuals, and is due to the gouging effect of the heavier talus boulders. The valleys crossing the Gippsland Road between Wilson's Quarry at Berwick and the Narre Warren Creek have all been carved out by minor laterals. They are due to a concave bend caused by the severance some distance from the main infilled valley of a tributary lava field trending west of Harkaway. The old Elizabeth Street Creek, Melbourne, was a minor lateral; it was formed after the Older Basalt was eroded from the vicinity of its basin, and had its source in the concave side of the Melbourne residual. The upper valley of the Ararat Creek at Upper Pakenham bears a similar relation to the eastern lateral (now captured) of the Upper Pakenham residual.

Besides being important factors in breaching a residual, minor laterals tend to throw light on the sinuosities of the Pre-Older Basalt valleys. The minor laterals in the vicinity of Melbourne seem to indicate that the Melbourne residual occupies a valley which changes its direction in the vicinity of Melbourne from south-east to south-west.

Process of breaching. Cross streams.

It is a seeming paradox that the more graded a lateral stream becomes the more remote is its chance of degrading a residual by lateral planation. The potent factors in reducing and breaching a residual are minor laterals which, cutting back on either side of a bend of a residual, attack it at points in close proximity. This is the prelude to the more drastic action of underground water, which is tapped when the head of the minor lateral saps its way under the reservoir represented by the porous beds of the old infilled valley. The breach, then, is accomplished by sapping due, in the first case, to the effect of meteoric waters, but subsequently to the combined action of both the meteoric and underground waters, aided, from time to time, by the rejuvenation of the laterals. The minor laterals on the east side of the Upper Pakenham residual afford examples of the combined action of meteoric and underground waters. Millane's, Copeland's, Moyle's, Taylor's and other springs all give rise to minor laterals, and it is a noticeable feature that landslips are conspicuous near these springs,

showing that the lava has lost its grip on the soft, underlying sediments. The minor laterals are also the channels for the drainage flowing down the steep slopes of the residual; the combined source gives a supply of water that lasts throughout the driest seasons.

When a residual has one lateral approaching maturity more rapidly than the other, the weaker one is sooner or later captured by the stronger one. For a certain distance downstream from the breach, the weaker residual is reversed. The eastern residual of the Lilydale residual is a case in point. (Fig. 5.) The hard quartzites in the vicinity of Cave Hill so retarded the formation of the eastern lateral, that Brushy Creek, the western lateral, captured it near where the Yarra flows across the north end of the residual. The eastern lateral valley is now occupied by three distinct streams, namely, Steel's Creek, flowing south through the breach, Olinda Creek (which at one time had its source in the Cave Hill quartzites) flowing north, also through the breach, and the Mooroolbark Creek, flowing both north and south on the south side of the Cave Hill quartzites. It is probable that the eastern lateral of the Lilydale residual never at any time assumed the characteristics of a strong lateral, owing to the hard flanking dacite rocks of the Mt. Dandenong massif.

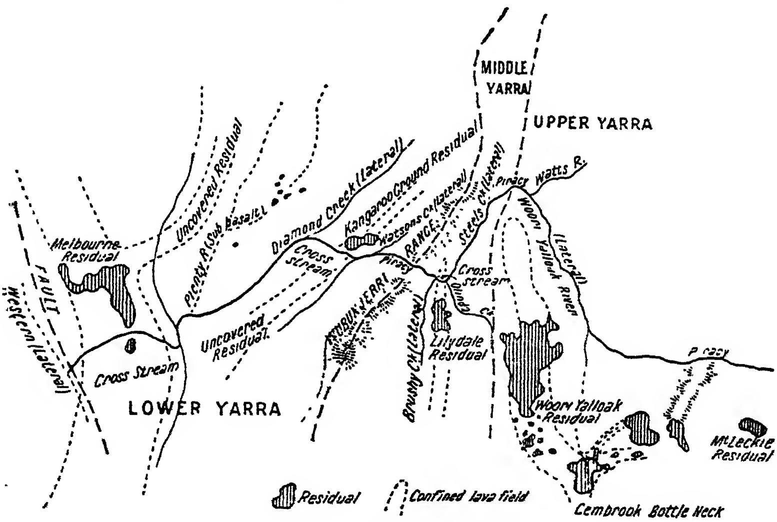


Fig. 8.

The accession of strength by breaching and capture to the headwaters of what was originally the weak lateral, is considerable; the stronger lateral also benefits by the capture. The breach be-

comes wider and wider as the captured head-waters more rapidly approach maturity, and the severed portions of the residual become more isolated.

The important part played by breaching, and the subsequent development of the cross streams, is shown in a typical way by the development of the Yarra (Fig. 5). The movement originally responsible for the breaching of the Melbourne residual in the vicinity of Melbourne occurred along a fault line parallel with the east side of Port Phillip Bay. Along this line of weakness at a later date the fault block of the Bay itself moved. The eastern lateral of the residual was diverted through the breach, and the subsequent rejuvenation extended along it and all its tributaries. A tributary of the eastern lateral was the Plenty River of the period, and an important tributary of the Plenty River was Diamond Creek, the western lateral of the Kangaroo Ground residual. The eastern lateral of that residual, viz., Watson's Creek, was diverted through a breach into Diamond Creek and rejuvenated. Subsequently the Wurunjerri Range was breached by a tributary of Watson's Creek, and the basin of the Middle Yarra diverted through the breach. The middle Yarra, previous to its diversion, found an outlet to the south of Lilydale either through the Lysterfield Gap or Dandenong. The immediate effect of the diversion was to reverse the direction of part of this southerly trending stream, so that we now have the western lateral of the Lilydale residual (Brushy Creek) flowing northwards, not southwards.

The breaching of the Lilydale residual and the subsequent capture and rejuvenation of the head-waters of the eastern lateral have been referred to (p. 147 ante). Belonging to an earlier period than the series of breachings and rejuvenations, just described in the development of the Lower Yarra, is the system of breaching and rejuvenation in the basin of the Middle Yarra. The eastern lateral of the Lilydale residual, rejuvenated, was powerful enough to breach the Woori Yallock residual, which resulted in the diversion of the Watts and the Woori Yallock River, which for a short time at the inception of the Intermediate cycle, had a southerly trend. The rejuvenation resulting from the breaching of the Woori Yallock residual probably accomplished the breach at Warburton, which resulted in the diversion of portions of the laterals of the infilled valley from the vicinity of Mt. Buller to Flinders.

From the fact that it is a series of laterals and breaches the Yarra has a circuitous trend, but the breaches give its valley a dominant gradient to the west. The Yarra and the upper portion

of the Goulburn are the only rivers in Victoria that have valleys with a distinctly westerly trend. The Latrobe, on the other hand, is the only river with a decidedly easterly trend. The three streams mentioned undoubtedly owe this peculiarity to their composite character; they consist of portions of laterals and cross streams pieced together. As evidence of the great strength of the breaching streams, it is suggestive that the Mt. Leckie residual trends east and west parallel to the cross streams of the Upper Yarra and Latrobe. The "high level lead" beneath, I am informed by a miner who has prospected it, falls to the south, which is to be expected from the trend of the confined lava field.

Residuals with resistant rocks on one side.

It has been observed under the heading of resistance, that the more resistant rocks of the areas are those altered at the contact of the Palaeozoic sedimentary and igneous series. The relative resistance of the altered rocks decreases away from the actual contact until the normal sediments are reached; there is therefore in the metamorphic zone, a gradation from the most resistant to the least resistant rocks. Where two contacts converge and are in close proximity a bottle-neck is formed, and all streams between the converging contacts are forced to seek an outlet through this bottle-neck. The Flinders bottle-neck was the main outlet for the Pre-Older Basalt streams of the Western Port system. It was formed by the converging contacts of the Arthurs Seat and Pyramid Point granite series. The Gembrook bottle-neck was formed by the converging contacts of the Dandenong and Pakenham granitic series.

The tendency of some Pre-Older Basalt streams was to cut back along the normal sediments immediately outside the aureole of metamorphism; as a consequence one side of their valleys was flanked by rocks that increased in resistance until they were among the most resistant rocks of the area, while those on the other side were among the least resistant. At other localities hard dacites are on one side of the valley and soft sediments on the other. In the development of laterals after a valley of this kind has been occupied by lava, the erosion of the lateral on the hard rocks is retarded or suppressed, but the lateral formed on the soft rocks on the other side develops quickly. This is due to the fact that the latter is the outlet for the whole of the drainage of the infilled valley.

In the bottle-neck, however, the lava is flanked on both sides by hard rocks—actually harder than the infilling lava; consequently, all streams developed later than the lava have to seek an outlet over it. The resulting retardation of the development of the system further back makes them easy captures to adjoining systems.

A good example of the retarding effect of a bottle-neck and its consequences is the sequence of events leading up to the capture of the eastern lateral—Woori Yallock River (so-called) of the Woori Yallock residual. Two confined lava fields converged southwards towards the Gembrook bottle-neck, the western one at the contact of the Mt. Dandenong dacite massif and the Dandenong granitic series, and the other or eastern one along the Pakenham granitic series. The converging contacts were only about a mile apart a little to the south of Gembrook, where the two confined lava fields joined. The gradients of the converging lateral streams were regulated by the lava in the bottle-neck over which they had to pass. Their development was comparatively slow and their general levels were always higher than the adjoining system of the Middle Yarra. When the streams of the latter system were rejuvenated, a tributary of the eastern lateral of the Lilydale residual breached or cut back round the lava occupying the westernmost valley of the Upper Yarra system and captured its eastern lateral. (Fig. 8.) The Watts River—the upstream portion of the captured lateral—was diverted through the breach, and the downstream portion was reversed as far as the Gembrook bottle-neck, and likewise diverted through the breach. Moreover, the lateral formed along the easternmost confined lava field converging towards the Gembrook bottle-neck, has been captured by the reversed lateral of the western confined lava field.

Ultimate configuration of residuals.

The frequent rejuvenation of the laterals and the consequent widening of the breaches tends to increase the isolation of the residuals, and at the same time reduce their extent and bulk. The shape shows the degree of encroachment of erosional forces, and may be illustrated by a fairly complete set of examples. (Fig. 9.)

The greater axis of the residual almost invariably lies between S 15°E. and S 15°W, suggesting that the trend of the Pre-Older Basalt valleys coincides with a system of erosion governed by the strike of the Palaeozoic sediments. The few exceptions may be explained by local irregularities due to unequal resistance or the

development of cross streams following breaching. A stream cutting across the metamorphic zone does so in the line of least resistance, that is, straight across it. The striking eastern prolongation of the Gembrook residual is a case in point.

Fig. 9.

Configuration of actual residuals showing variety of form. All drawn to same scale and oriented.

The section of a residual with only one lateral developed represents that of a bluff. The steep ascent from Cockatoo to Gembrook represents the ascent of such a residual; and when the ascent has been accomplished, the railway line runs along a comparatively level surface at the top of the residual. The last portion of a residual to succumb to erosion is usually more or less circular.

"Uncovered residuals."

A physical connection between two residuals separated by the valleys of cross streams may be recognised by "uncovered residuals," or the spur or range left after the lava covering has been removed. (Fig. 8.) If they are in the valley of a cross stream, their general trend is towards the cross stream. An example of such, which forms an important link in connecting up the valley of the stream flowing from the vicinity of Mt. Buller to Flinders, is the ridge (part of the Main Divide) trending south-westerly from Woods' Point. The Yering Gorge described by Mr. Jutson[1] has probably been cut through an uncovered residual in the trail of the Lilydale residual. The watershed between Dandenong and Burwood Creeks is probably another example. There are numerous typical examples to be seen in the Western Port area on the slope from the Yarra watershed towards the Koo-wee-rup Swamp.

The southern watershed of the Yarra basin and the Main Divide are the only east and west trending ranges on the area under consideration. They belong to the period when the cross streams

1 Vide Bibliog., No. 12.

became the dominant factors in the erosion of the systems, and are essentially ranges formed by erosion. When the lava in the Gembrook bottle-neck disappears the drainage of the Middle Yarra may again find an outlet in this direction. The watersheds between the lateral valleys are still the most conspicuous ranges and spurs of the systems, and trend north and south; even in the Yarra basin the trend of the ridges between the laterals on its south side disclose to some extent a southerly gradient.

Isolation of residuals.

One has only to travel in the direction of the infilled valleys to realise that residuals are separated by the valleys of the cross streams, and that when allowance is made for the amount of lava removed by them, an approximate idea of the length and extent of the confined lava fields may be formed. For instance, if we take the confined lava field that occupied the valley of the Pre-Older Basalt stream that originated somewhere near Mt. Buller and trended towards Flinders, we encounter a number of residuals isolated by east or west valleys—the valleys of the cross streams. In the trend of this ancient valley, the Mt. Buller residual is separated from Klingsporn's residual by the Howqua. Klingsporn's residual is separated from the Woods Point residual and "uncovered residual" by the valleys of the Jamieson and Goulburn, the Woods Point residual and "uncovered residual" is separated from the Mt. Leckie residual by the valley of the Yarra, the Mt. Leckie residual is separated from the Neerim residual by the valley of the Latrobe, and the Neerim residual is separated from the Drouin residual by the valley of the Tarago. Southwards from Drouin the lava may exist as a connected sheet; at any rate, it belonged to an extensive lava field with much of the erosion hidden by block faulting and masked by recent deposits. Other examples could be cited, but the geological map of a district will disclose more at a glance than a detailed description.

When the point of time at which any of these cross streams actually breached the confined lava plain is determined accurately, a connected geological history of not only the evolution of the stream systems, but also the accumulation of deposits in their valleys will be possible.

The repeated rejuvenation of the streams that have accomplished the breach has in many cases been the result of block faulting, but caution is necessary lest one should ascribe to a fault what may be

due to differential erosion. Although, for example, the Dandenong-Cape Schanck fault may have been, to some degree, responsible for the encroachment of the streams belonging to the Port Phillip system into the Western Port area in the vicinity of Narre Warren and Cranbourne, by far the greater factor was the differential erosion of the two systems. The hard lava in the Flinders bottle-neck, over which all the drainage of the Western Port system had to pass, so retarded its development that the comparatively rapid development of the Port Phillip system made capture relatively easy. The Wurunjerri Range[1] being composed of soft sediments in the vicinity, Dandenong was the most probable locality for breaching.

III.—Evolution of a Residual from an Extensive Lava Field.

The Western Newer Basalt Lava Field.

On the extensive and comparatively young Newer Basalt lava field of Western Victoria, many of the drainage channels still follow the courses assumed by them at the cessation of volcanic activity and their disposition in relation to the softer rocks beneath the lava is quite arbitrary. There are areas, however, where the softer sediments along the Pre-Newer Basalt watersheds have been exposed by vertical erosion and where sapping has commenced along the line of least resistance, that is along these watersheds. A portion of the lava plain north of Melbourne affords a typical example. The Saltwater River has sapped its valley along the old watershed between the Pre-Newer Basalt valleys coming from the directions of Romsey and Wallan, and joining in the vicinity of Bulla. Both the Saltwater River and Emu Creek will ultimately become laterals (Fig. 2) to a residual, the protective covering of which is lava belonging to the Newer Basalt. In the central western area of Victoria there are many examples of confined lava fields belonging to the newer volcanic series, where laterals are cutting back on the softer rock along their edges, and all the erosional factors are operating to produce the residual just as they have in the Western Port area from the older lavas. The confined lava plains of the western area extend northwards for many miles but southward for a limited distance to where they join the extensive lava field of Western Victoria south of the present Divide. The circuitous line marking this junction is where what is here

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[1] Vide p. 157, post.

termed the "cross-lateral"[1] will form, and is the probable direction of a great valley to be developed perhaps under the same condition as that much earlier valley referred to by Prof. Gregory[2] as the Great Valley of Victoria.

The residual is the outcome of the erosional processes on both the extensive and confined lava fields, but peculiar considerations affect the transition from each type of lava field. In the case of the confined lava field (Fig. 1) the lateral streams are formed on the softer rocks at the edge of the lava, and relatively near the infilled stream; but on the extensive lava field (Fig. 2), the lateral streams may form along uncovered watersheds anywhere between the infilled streams. In other words, from a confined lava field, laterals form comparatively close parallel valleys, and the resulting residuals are restricted in size, while the laterals developed on an extensive lava field are usually far apart, and extensive residuals are the result. Moreover, the flanking softer rocks exposed by a lateral evolved from an extensive lava field are always below the lava covering of the residual, which is not the case in the development of a residual from a confined lava field, where, on the opposite side of the lateral valley to the residual, they are both above and below the level of the lava.

Apart from these and other minor distinctions, striking parallels in development are forthcoming by a comparison of the still youthful erosion of the western cycle from the newer volcanic series, and the mature erosion of the eastern cycle from the older volcanic series.

Development of a Residual from an Extensive Lava Field.

Streams that formed wholly on an extensive lava field flowed in the direction of the gradient which, according to Harker,[3] is very slight. Although their initial directions were dominated by this gradient, their once seemingly aimless courses were due to such factors as sag, the edges of flows, faults, etc. When, however, one of these streams had cut down to the underlying less resistant rock, the factors that governed its development may be summed up in the following:—

(a) They cut back along the line of least resistance, i.e., along the line of least thickness of overlying lava.

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1 Vide p. 155, post.
2 Bibliog., No. 4
3 Vide Bibliog., No. 6.

(b) The least thickness was usually along the pre-basalt ridges and watersheds.

(c) When the line of least resistance was reached cutting back and sapping commenced along it, and a new valley was initiated—that of a lateral of a prospective residual; the old stream, by domestic piracy, became a tributary to this new stream.

It is apparent, therefore, that the valleys formed on an extensive lava field, though at first seemingly arbitrary as regards direction, eventually carve out valleys parallel to the sub-basalt (pre-basalt) valleys, but on the watersheds between them. This is the beginning of a process of isolation. The residuals are formed by the operation of the same erosional factors as in the case of the confined field and the evolution proceeds on precisely similar lines.

Junction of Confined and Extensive Lava Fields.

Cross Lateral.

Arising from the fact that the lateral streams of a confined lava field cutting back on the soft rocks at the edge of the infilling lava, are relatively close compared to the lateral streams formed on an extensive lava field, the vicinity of the junction of a confined and extensive lava field is characterised by typical and important changes in the conditions of erosion. It is the critical locality where, when erosion has reached a certain stage, one class of lateral crosses over and assumes the characteristics of the other. This is usually effected by its cutting round the spur of softer rocks flanking the confined field,[1] to the line of least resistance on the extensive field, that is, in the direction of this spur under the lava.

This critical locality affords perhaps the most advantageous conditions for piracy in the whole drainage system. The lateral streams of both classes are in juxtaposition, and the distance between them has in places been halved—in fact, a portion of any possible cross stream with piratical tendencies has been formed by the crossing over of the lateral. Such a stream precipitated, say, on the relative upthrow side of a fault parallel to the trend of the lateral streams, or encroaching from an adjoining more powerful system, finds this locality a vantage point. As streams of considerable length are usually involved, the piratical stream receives a powerful accession of strength.

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1 At this critical point gradient sometimes overcomes resistance and the lateral streams of the confined lava fields maintain their directions.

From the fact that the lavas of Western Victoria are comparatively recent, and those of Eastern Victoria relatively old, typical instances of the cross-lateral in all its stages are difficult to select. Perhaps the confluence of the confined and extensive lava plains to the south of Ballarat provides as good an example of the preliminary conditions leading to the formation of a cross-lateral, as may be found. (Fig. 10.)

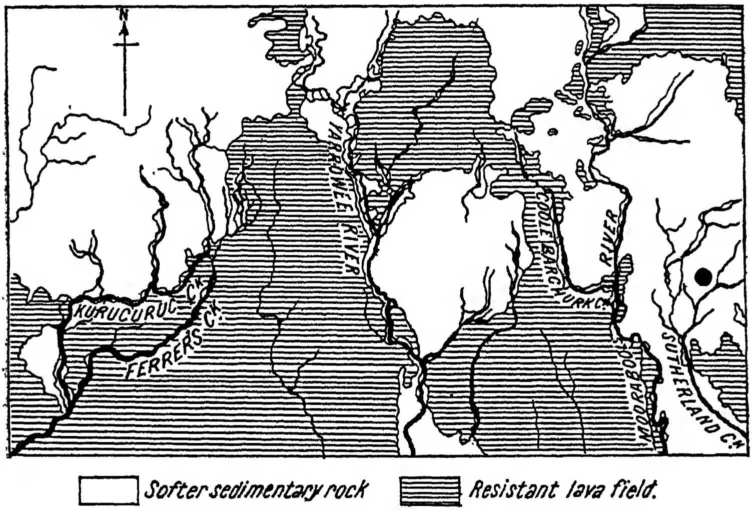

Fig. 10.

Typical conditions for the subsequent development of the cross-lateral junction of confined and extensive lava fields, south of Ballarat. Scale 8 inches to 1 inch.

The Hallam Creek furnishes a typical example of a mature cross lateral, Assisted by the hard rocks at Flinders, which retarded all streams seeking an outlet in that direction, strengthened by the rapid and unretarded erosion of the Port Phillip system, and rejuvenated by the Cape Schanck-Dandenong fault, the head-waters of a stream belonging to the Port Phillip system have cut back to the east of Dandenong, and encroached on and captured all the laterals of the Western Port system up to and including the eastern lateral of the Berwick residual, and possibly even further afield. It has diverted the lateral streams coming from the north, and reversed the direction of their continuation to the south. The streams concerned are the Narre Warren Creek (the original length of which is shown on Fig. 6), two laterals (in part) of the Cranbourne residual, which have been reversed, and some minor laterals.

Significance of the Cross-lateral.

The speculations arising from a consideration of the immense power gained by the cross-lateral by successive captures, are important and interesting. It is suggested that the Great Valley of Victoria[1] may have had its beginning in this way, and although crustal movements, block faulting and other factors may have ultimately contributed to its formation, portion of it at least east of Melbourne may be thus accounted for. How powerful the Hallam Creek actually was may be conceived by the fact that its flood plain is in many parts a mile wide, although, through beheading, it now carries a mere trickle. The part played by this stream in the sedimentation of the Carrum Swamp was considerable.

IV.—Distribution of Residuals and Classification of Valleys.

Confines of the two systems.

The Older Basalt residuals of the area dealt with in this paper are along the trend of Pre-Older Basalt valleys (Fig. 3) belonging to two well-defined systems, namely, the Western Port and the Port Phillip. At the cessation of volcanic activity the watershed separating these two systems extended from Arthur's Seat to Frankston, and was due to the resistance offered by the metamorphic rocks at the contact of the Palaeozoic sedimentary and igneous series. Between Frankston and Dandenong it was composed of less resistant sediments, probably of Palaeozoic age. From Dandenong it followed the metamorphic rocks, to the west of that town, to Wheelers' Hill, thence to Vermont, thence through Ringwood to the quartzites running parallel to Brushy Creek, Its continuation was the line of hills formed by these quartzites through Mt. Graham, Big Hill, Conical Hill, and Bald Hill, to about eight miles east of The Gap, beyond which point it has not been defined. This watershed has been referred to in this paper as the Wurunjerri[2] Range. Parts of the drainage system of the Yarra referred[3] to by Prof. Gregory as the basins of the Middle and Upper Yarra are here assigned to the Western Port system.

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1 Vide Bibliog., No. 4.

2 The Wurunjerri tribe inhabited the Yarra basin.

3 Vide Bibliog., No. 4.

Residuals of the Western Port system.

The residuals along the valley of the main pre-Older Basalt stream of the Western Port system, from Mt. Buller to Drouin, have already been mentioned (p. ante). The Drouin residual has been truncated southwards by a block fault. At Lang Lang, south of Drouin, the basalt is 436 feet below the surface, but it again appears at the surface on the mainland at the north-east corner of Western Port Bay. From the last mentioned point to Flinders and Cape Schanck, it probably exists as an unbreached sheet. This stream is identical in direction with Prof. Gregory's Tarago, but since the present Tarago is much more recent, and, moreover, is a cross stream, another name would be more appropriate, and it will be referred to in future as the Flinders.

A large tributary of the last mentioned stream had its source somewhere north of the Woori Yallock residual, and was probably identical in its head-waters with the Watts. Its course is represented by the "uncovered residual," of Steel's Range, the Woori Yallock residual, the Gembrook residual, the Pakenham residual, and by a line of conspicuous "uncovered residuals" disappearing into the Koo-wee-rup fault block towards the trunk stream. Above the Gembrook bottle-neck this tributary received a tributary from the north-east; it originated on the westerly slope of Mt. Donna Buang.

Another large tributary had its source north of the Kinglake Gap and is probably represented in its head-waters by the reversed Yea River. South of the Kinglake Gap its course is represented by the uncovered residual between Steel's Creek and the parallel valley to the west, and still further to the south, by the Lilydale residual. It then trended southwards through the Lysterfield Gap below which it is represented by the Harkaway, Berwick and Beaconsfield residuals. It joined the trunk stream somewhere in the vicinity of French Island.

A smaller tributary had its source to the north of Cranbourne, flowed in the vicinity of the Cranbourne residual, and joined the main stream or a tributary of it in the vicinity of French Island.

There are many smaller residuals which from their configurations, positions and characteristics lead one to believe that they have been developed from infilled tributaries or by cross streams.

Residuals of the Port Phillip system.

The connection between the Melbourne and Bellarine residuals is problematical, but it is certain that an important stream received tributaries from different portions of the system and passed southwards over the Bellarine Peninsula. The extension north of the Bellarine residual may be traced under the waters of Port Phillip Bay by the bathymetrical contours. The trend of the stream is represented by the Older Basalt lava, east of Sunbury, Bulla, Broadmeadows, Essendon, Melbourne and South Melbourne, all situated on the Melbourne residual. The western lateral of the Melbourne residual lies beneath the Newer Basalt extensive lava field, but its eastern lateral is now a confined Newer Basalt lava field, and may be easily located by the laterals forming on either side. (Fig. 4.)

Apart from the Melbourne and Bellarine residuals, the Kangaroo Ground and some smaller residuals are all that remain to show the erosion antecedent to the Newer Basalt.

A systematic classification of valleys.

From the several types of erosion described, a tentative classification of many of the streams, according to the factors that started the formation of their valleys, may be attempted. Starting with the oldest, it is proposed to adopt the following classification :—

(1) Pre-Older Basalt cycle.
(2) Older Basalt cycle.
(3) Intermediate cycle.
(4) Newer Basalt cycle.
(5) Post Newer Basalt cycle.

(1) *Pre-Older Basalt Cycle.*

The head-waters of some streams may still belong to this cycle; probably the Watts River is still occupying a Pre-Older Basalt valley. Many of the valleys are still intact below the Older Basalt residual.

(2) *Older Basalt cycle.*

Short cycles which started after each successive flow of the older lavas—in mining phraseology, "false bottoms." It may be found possible to correlate the soft strata between the hard basalt disclosed in the Lang Lang, Phillip Island, Flinders and Cape Schanck bores.

(3) *Intermediate Cycle.*

This cycle is designated "Intermediate," because on the Port Phillip area it covers the stream development during the period between the Older and Newer Basalts. Many of the streams have been repeatedly rejuvenated during that period, but I am guided by the fact that their valleys were first formed at a particular time during the cycle. They may be classified under the system to which they belong.

PORT PHILLIP SYSTEM.

Lateral Valleys—
- Diamond Creek.
- Watson's Creek.
- Gardiner's Creek.
- Lake Connewarre.
- Valleys now occupied with Newer Basalt confined lava fields.
- Yarra (parts).

Cross Lateral Valleys—
- An old valley in the vicinity of Springvale and Clayton.

Minor Lateral Valleys—
- Old Elizabeth Street Creek.
- South Yarra Creek.
- Moonee Ponds Creek (part).

Cross Stream Valleys—
- Yarra, at Melbourne.
- Yarra, south of Kangaroo Ground.
- Western end of Channel of Corio Bay.
- Several valleys infilled with Newer Basalt.

WESTERN PORT SYSTEM.

Lateral Valleys—
- Woori Yallock Creek.
- Bunyip River.
- Narre Worran Creek.
- Cardinia Creek.
- Deep Creek (part).
- Steel's Creek.
- Olinda Creek (part).
- Brushy Creek (part).
- Mooroolbark Creek (part).
- Dandenong Creek (part).
- Clyde Creek.
- Cranbourne Creek.
- Hallam Creek (part).
- Yarra (parts).

Cross Lateral Valleys—
- Hallam Creek (part).

Minor Lateral Valleys—
- Creeks crossing Gippsland Road between Narre Worran Creek and Berwick residual.
- Several tributaries of Woori Yallock River. Other unnamed creeks.

Cross Stream Valleys—
- Yarra, north of Lilydale residual.
- Brushy Creek, south of Lilydale residual.
- Yarra, a little west of confluence with Watts.
- Yarra, upstream from Warburton.
- Headwaters of Latrobe River.
- Tarago River.
- Some channels of Western Port Bay.
- Ararat Creek (head waters).

(4) *Newer Basalt Cycle.*

Short lived cycles between successive flows of newer lavas.

(5) *Post Newer Basalt Cycle.*

PORT PHILLIP SYSTEM.

Lateral Valleys—
- Yarra, between Heyington and Fairfield.
- Merri Creek (part).
- Darebin Creek (part).
- Moonee Ponds Creek (part).
- Saltwater River.
- Riddell's Creek.
- Hovel's Creek (part).

Valleys formed on Extensive Lava Field—
- Kororoit Creek.
- Werribee River.
- Skeleton Water Holes.

Synopsis of Paper.

The lava residual is the result of the greater resistance to erosion of basaltic lavas compared to that on the softer rocks contiguous to them.

The development of the Older Basalt residual is characterised by three readily defined cycles—namely, (1) the Pre-Older Basalt cycle, (2) the Older Basalt cycle, and (3) the Intermediate cycle. The development of the Newer Basalt residual is also characterised by three cycles—(3) the Intermediate cycle, (4) the Newer Basalt cycle, and (5) the Post Newer Basalt cycle.

The Intermediate and Post Newer Basalt cycles during which the actual development of the residuals took place were, at their inception, characterised by two types of lava field, formed during the preceding cycle, namely—(a) the confined lava field which was contained within the watersheds of the Intermediate cycles, and (b) the extensive lava field where the lava escaped the limits of these watersheds.

The development of a residual from a confined or extensive lava field proceeded, at its initial stages, on somewhat different lines. From a confined lava field, a residual was developed by lateral streams on the soft rocks at the parallel edges of the lava; from an extensive lava field, the development was by lateral streams on the

Pre-Older Basalt watersheds in the case of an Older Basalt residual, and the watersheds of the Intermediate cycle in the case of a Newer Basalt residual.

The tributary of a lateral stream that has its source on the contiguous residual has been termed a minor lateral and a stream (usually a well-developed minor lateral) that has actually breached a residual, a cross stream.

The probable extent of the Bass Strait lava field is commented on. The gradients of lava fields are shortly referred to. The thicknesses and extent of other great lava fields are given.

The type of erosion of the Pre-Older Basalt cycle of Western Port is considered to be that characterising a mountain region. Only its head-waters are represented between Mt. Buller and Flinders. The type of erosion of the Port Phillip system on account of the few Older Basalt residuals exposed is problematical.

The confined lava fields merged into the extensive lava fields in the vicinity of the railway between Melbourne and Drouin. The Western Port extensive lava field converged towards Flinders, and passed through a bottle-neck there formed by the converging contacts of the Arthur's Seat and Pyramid Point granitic series. The extensive lava field of the Port Phillip area is thought to have been less extensive owing to the more graded state of the drainage system.

The effect on the lava gradient of bottle-necks and lava fissures opening across valleys is considered.

Deductions are made from the evidence of borings put down at various localities on the area under consideration. The strata passed through is tabulated and classified. The Older and Newer Basalts are regarded as bench-marks of great stratigraphical and physiographical importance, marking the termination or inception of the five cycles mentioned.

The conditions affecting the development of a residual from a confined lava field are responsible for three stages in their orderly evolution—(a) the rocks on one flank being a little more resistant than the lava, one lateral is formed, (b) the rocks on one flank being somewhat less resistant than the lava, while that on the other flank belongs to the least resistant class of rocks, two laterals are formed, but one approaches maturity much more rapidly than the other; (c) the rocks on both flanks offering comparatively little resistance, two laterals of relatively equal importance are formed.

The relative resistance of the rocks of the area is tabulated, and the governing factors referred to.

Short cycles of erosion during the Older Basalt cycle are considered, and the possibility of their having continued for a relatively long period is negatived. The possibility of an Intermediate phase of volcanic activity between the Older and Newer Basalts is also negatived.

The initial stage of the Intermediate cycle involving the development of the lateral streams is described. Their development is shown to be governed by the concomitant factors of gradient and resistance; the gradient was regulated for the most part by the extensive lava field and infilled tributaries.

The formation of minor laterals is explained. The action of their head-waters is the prelude to the breaching of a residual.

The development of the cross stream is accompanied by the capture and reversal of the opposite lateral. The development of cross streams is adduced to explain the composite character of the Yarra.

The development of residuals with resistant rocks on one flank is enlarged on. The profound effect of bottle-necks on the subsequent development of the Western Port system is indicated.

The ultimate configuration of residuals is described and illustrated.

The "uncovered residual" or the spur or range left after the removal of the lava is shown to afford a physical connection between existing residuals.

Residuals are shown to be isolated by the width of the valleys of the cross streams.

The piracy of certain streams belonging to the Western Port system by the adjacent Port Phillip system is considered to be due more to differential erosion than to faulting.

The development of a residual from an extensive lava plain may be more conveniently studied on the Newer Basalt lava field.

The stream development on an extensive lava field is primarily governed by such factors as sag, the edges of flows, faults, etc., and their trend is quite arbitrary as regards the submerged watersheds.

The distinguishing differences between a residual developed from a confined and one developed from an extensive lava field are indicated.

The manner in which a lateral stream of a confined lava field passes on to the extensive lava field is described, and the development of the cross lateral is explained.

The significance of the cross lateral in the development of the Great Valley of Victoria is commented on.

The sequence of residuals in the Pre-Older Basalt valleys and the courses of the streams are indicated.

A tentative classification of many of the valleys of the two stream systems is attempted.

Acknowledgments.

My thanks are due to Mr. H. Herman, Director of the Geological Survey of Victoria, who kindly sanctioned the publication of this paper, for his helpful criticism and facilities placed in my way.

To Prof. Skeats I am particularly indebted for his exhaustive and suggestive criticism of the paper in its original form.

Mr. F. Chapman, of the National Museum, has placed his unrivalled knowledge of the Victorian Tertiaries at my disposal; for this and other assistance I desire to acknowledge my great indebtedness to him.

It will be recognised that the execution of the plans and sections accompanying this paper necessitate constructive as well as ordinary draughtmanship. I desire to thank Messrs. C. Glover, T. Dewey and W. E. Bennett, of the Geological Survey Draughting Branch, for the care they have taken with them.

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[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART I., 1918].

ART. VIII.—*On the Age of the Bairnsdale Gravels; with a note on the included Fossil Wood.*

BY FREDERICK CHAPMAN, A.L.S., &c.
(Palaeontologist, National Museum, Melbourne).

(With Plate X., and 1 text figure).

[Read June 13th, 1918].

Occurrence.

The uplifted coastal plain, which extends from the hill-ranges of South Gippsland on the west to Cape Howe on the east, is covered with a sheet of coarse gravel and sand, in which are frequently found silicified tree-trunks with their structure excellently preserved.

Some two or three years ago, whilst travelling from Bairnsdale to Orbost by the new railway line then in course of construction, I was impressed with the enormous extent of these gravel beds which were met with along the greater part of the country traversed. On examination, the gravels were found to contain many kinds of hard rock, both quartzitic and igneous, undoubtedly derived from the high lands to the north. Dr. T. S. Hall has remarked upon this gravel sheet, in its occurrence in the western area, as follows:—[1]

"A striking feature of the Tertiary plateau to the north of the lakes is the presence of a great sheet of gravel and sand which covers the district, as seen on the railway line from Flynn's Creek to Bairnsdale. West of Sale sands predominate, but from Sale to Stratford coarse gravels are common, and the same may be said of the country from there to Bairnsdale. The same gravel plateau, deeply trenched by streams, extends along the Buchan road, with but a slight intermission, as far as Stony Creek. The rocks composing the deposit vary considerably, in places rounded quartz predominates, but in others quartzites and ferruginous hardened sandstones are very common. They evidently represent a waste sheet from the mountains to the north."

In a traverse from Bairnsdale to Neumerella I noticed these torrent gravels usually rested on, or passed into, fine sand; more-

1 Some Notes on the Gippsland Lakes. Vict. Nat., vol. xxxi., June, 1914, p. 33.

over, the beds were especially developed (as seen in excavations along the railway line) from Bairnsdale to the Nicholson River. They again became predominant from Mossiface to Bruthen. From Stony Creek through Nowa Nowa to Tostaree as far as Hospital Creek they appeared in sheets of considerable thickness, whilst in nearing the Snowy River basin they were again seen. At 23 miles 18 chains east of Nowa Nowa the Bairnsdale Limestone reappeared and the section in the cutting shewed torrent gravel 3 feet, resting in a great thickness of limestones and marls of Janjukian or Miocene age. The gravel bed near Neumerella shows a thinning out owing to uplift and denudation in this district.

The thickness of the gravels varies greatly according to local position, and, as we might expect, they are thickest in those areas which, during their deposition, were subject to subsidence and estaurine influence. Thus, in the trend of the old valleys of the Macallister and Mitchell Rivers, we have such evidence from the borings put down in search for water. At Paynesville a pebble bed was met with at 100 feet which, in all probability is the same as the gravel bed now under discussion; at 160-260 feet Kalimnan fossils from the same boring were identified by the writer, whilst deeper still the Janjukian strata were in evidence.[1] And here must be explained an apparent discrepancy of opinion regarding the much greater thickness of these gravel beds which Dr. Hall[2] was led to assume from data given to the Conference on Artesian Water in 1913, since he remarks that "At Paynesville water was struck at 520 feet in terrestrial gravels." The deposit in question belongs to the older series, and is Miocene or Janjukian, the mistake having arisen from the bore-foreman describing the silty, shelly (marine) deposit as "terrestrial gravel." This curious error shows the necessity of a palaeontological examination of the deposits before any accurate conclusion as to origin can be arrived at. It is also extremely probable that the same results would obtain from an examination of the boring products of Sale and Fernbank, also alluded to by Dr. Hall.

As we pass over to the eastern border of the ancient Gippsland Bight we notice that much of the coastal plain has again disappeared beneath the sea, and we get only the inner border of the deposit, naturally with coarser boulders, and lying against the flanks of the old rocky coast-line. This character is maintained

1 Chapman. Cainozoic Geology of the Mallee and other Victorian Bores. Rec. Geol. Surv. Vict., vol. iii., pt. iv., 1916, p. 402.

2 Vict. Nat., vol. xxxi., June, 1914, p. 33.

on to Cape Howe, where it disappears against the truncated rocks of the Pacific Coast.

Age of the Gravel Bed.

From the geological evidence of the formation of a peneplain with leaf-beds and Miocene, or "older basalt," lava flows in the mountain regions of Gippsland, it may be concluded that the great uplift of this fairly mature area, geographically speaking, took place at the close of the Miocene and Lower Pliocene (Kalimnan) times, named by E. C. Andrews "The Kosciusko Period."[1] A range of high land running more or less parallel to the south-eastern coast of Australia was then elevated to heights varying from 2000 to 7300 feet above sea-level. Following upon this, along the Gippsland Lakes district, there is evidence of a secondary subsidence, which is progressing even down to the present time. This Late Pleistocene to Recent downward movement is proved by the drowned ends of river valleys, as pointed out by Dr. Hall,[2] which are seen at the North Arm of Lake Cunninghame, Lake Bunga and Lake Tyers. Further proof of this subsidence is met with in the great depths of the river valleys near the coast; and in that district in 1915, I had the opportunity of seeing the pile driving for the Nicholson River Bridge, where 80 ft. of alluvium had been penetrated without reaching bedrock. That this subsidence, howeevr, is intermittent, is proved by finding not very far away, low cliffs of Kalimnan sands well above sea-level and surrounded by the torrent gravel.

So far as my own observations go, the torrent gravels with their large boulders and rounded fragments of silicified wood seem to rest on or pass downwards into fine sand; at other times to rest on older rocks (Janjukian). The lower sands are undoubtedly of Kalimnan age, as they represent the Moitun and Boggy Creek ironstone series of McCoy, and also the Jimmy's Point shell-marl. This sequence is supported by evidence already published by Messrs. Dennant and Clarke,[3] for in a section of Underwood's Cliff at Bellevue, N.W. of Bairnsdale (see woodcut), we have a ferruginous sandy conglomerate pasing upwards into heavy gravel wash (=torrent gravel) with a fossil log; this is underlain by fourteen feet of ferruginous fossil blocks (containing Kalimnan fossils),

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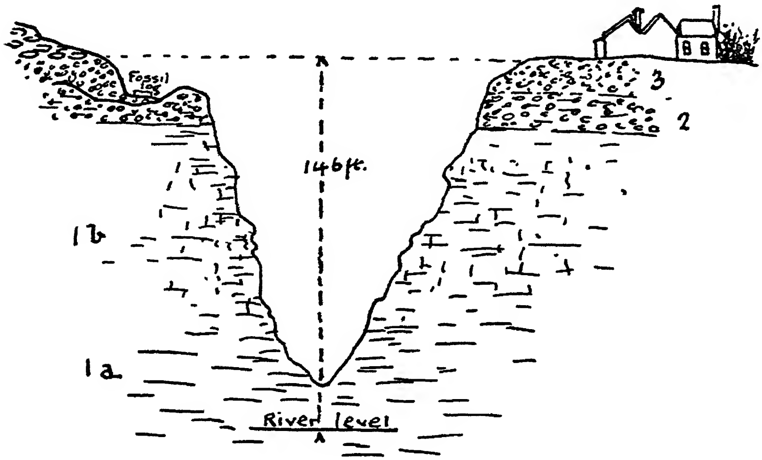
1 Geographical Unity of Eastern Australia. Journ. and Proc. R. Soc. N. S. Wales, vol. xlix., pt. iv., 1910, pp. 420-480.

2 Vict. Nat., vol. xxxi., 1914, p. 32.

3 Proc. Roy. Soc. Victoria, vol. xvi. (n s.), pt. i., 190?, p. 2?, pl. iv.

then four feet of clay, eighteen feet of limestones with fine gravel, four feet of yellow limestone and one hundred feet of alternating hard and clayey limestones. Seeing that the ferruginous bed at Underwood's contains Lower Pliocene fossils, the torrent gravel which rests upon it, on acount of its different lithological structure, will be post-Kalimnan. Allowing for the great physiographic



Section at Underwood's, Lower Mitchell River. After Dennant and Clark, with additions. Showing relative position of Gravels with Silicified Wood.

1a—Janjukian marls; 1b—Janjukian limestone; 2—Kalimnan fossiliferous ironstone; 3—Gravels (Werrikooian), with silicified wood.

changes which have taken place since Kalimnan times, the beds of gravel immediately following could hardly be younger than Upper Pliocene or Werrikooian. That Dr. Hall was inclined to regard these gravel beds as older, that is, of Kalimnan age, can be gathered from his remarks in the paper on the Gippsland Lakes,[1] where he says: "Clear evidence of the age of the gravels is shown at Red Bluff, near the mouth of Lake Tyers. The cliffs here consist of yellow and grey sands crowded with *Arachnoides incisa*, Tate, and are of Kalimnan (? Miocene) age. The sandstones contain a few quartz pebbles, which form intercalated sheets in the upper part of the cliff." If, however, we regard this upper bed as distinct from the lower yellow and grey sands, we must necessarily conclude that they are of later age than the echinoid-bearing sands,

1 Loc. supra cit., 1914, pp. 33, 34.

and therefore Post-Kalimnan or Werrikooian, and this conclusion appears to agree with the evidence from Bellevue and the general sections along the Orbost railway line. Moreover, these lower sands with echinoids are, *prima facie*, marine, whilst the torrent gravel by the nature of its composition, as the débris of mountain streams, is undoubtedly of terrestrial origin.

This term "terrestrial gravels," was previously used by Dr. T. S. Hall in his paper quoted, and who refers to its origin as "a waste-sheet from the mountains to the north."[1] If this subaerial origin were doubted, the following points should settle the question :—

1.—Were the gravels of marine origin the pebbles would have been of a more uniform size, due to sorting by wave action, and the finer sand carried away. The Bairnsdale gravels consist of large and small boulders and pebbles embedded in fine and coarse sand.

(Darwin, in describing the gravels of the sloping terraces of the Cordillera,[2] shows how terrestrial gravels of the terraces consist of waterworn pebbles, angular, subangular, and rounded, and are embedded in fine sand; whilst the lower talus plain, which he concludes has been subjected to marine influence, has well rounded pebbles interstratified with fine sand. The present writer endorses these distinctive points from observations made on raised beach deposits both round the British Islands and on the Australian coast.)

The same physical structure is seen in the case of glacial tills, where sorting by levigation has had no chance to work.

2.—In a marine beach or littoral deposit, sea-shells, shell-fragments or encrusting organisms would almost invariably be present. For example, the gravelly marine beds (Janjukian and Kalimnan) of the Paynesville Bore *do* contain marine shell-fragments. The Patagonian beach gravels have the pebbles frequently encrusted with marine organisms.

3.—The presence of silicified (derived) blocks of fossil wood clearly point to a terrestrial origin, for if drifted wood it must have been silicified subsequently to deposition, yet there is no trace of the siliceous cementation of the bed containing the wood. Moreover, all drift wood in fossil deposits seen by the writer showed traces of attack by marine organisms as *Teredo* and worms.

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1 Victorian Naturalist, vol. xxxi., 1914, p. 33.

2 Darwin. Geol. Observations on the Volcanic Islands and parts of South America, visited during the voyage of H.M.S. Beagle, 2nd ed., 1876, pp. 286-9 and pp. 290-92.

4.—The unconformable relation of this gravel bed to the underlying shallow marine deposits, and its aspect in regard to the present physiography of the coast allow of no other conclusion than that it is terrestrial.

Age of the Fossil Wood.

(a) *Evidence for Kalimnan Age.*

Although the gravels containing the logs and pebbles of silicified wood have been shown to be of Werrikooian age, the timber, being already mineralised, must have had an earlier origin. It has been previously noted that some of the Kalimnan shallow marine beds are replaced in certain areas by fine silicious sands, and it is reasonable to assume that there, by their freedom from marine fossils, they were parts of old land surfaces. It is probable that upon these Kalimnan sands grew the tall timber which gave rise to the silicified tree stems. As these old pioneers of our present heritage of the Gippsland forests arrived at maturity, they would in the course of events succumb to the fury of wind and rain and become buried in silt and sand. Through the percolation of alkaline water they would readily yield to silicification, much in the same way as the *Acacias* and other trees and shrubs of the Cairo petrified forests were formed.

That these trees did not grow in any profusion on the slopes of the northern ranges is an inevitable conclusion, seeing that at that time, as now, there must have been a great deal of vertical erosion on the sides of the hills, and that the natural home for the forests would be along the foothills and flats. There the accumulated remains of logs and branches would be gathered, where quieter conditions of deposition would obtain, inducing fairly rapid silicification. The same forces which would break up the surface of the older beds to form the Werrikooian gravels would also bring down the fragments of volcanic rocks and quartzites from the high lands to the north.

(b) *Evidence for Janjukian Age.*

On the other hand it might even be proved by the collection of further evidence from stratigraphical relationship, that the silicified wood was derived from quartzitic deposits under the older (Miocene) basalt-lavas, of which there are numerous remnants along the upper reaches of the Dargo and Tambo Rivers. This could

only be arrived at by a careful search of valley sections in those areas, for evidence of silicified tree-stems *in situ.*

With regard to the silicification of loose sand overlain by basalt, it is, for example, well known that the sands of Kalimnan age in the Melbourne area which would otherwise be of loose texture, where covered by the newer basalt, are consolidated and silicified, it may be assumed, by alkaline waters from the overlying lavas, which either contained dissolved silica or dissolved it during percolation; and frequently pieces of wood are found in the sands which have been preserved through the reactions from the lava above. It is therefore easy to conceive that in the same way the thorough silicification of logs of wood might occur in the Miocene deposits of the uplands and plateaus of Gippsland, where leaves of Eucalypts and fronds of ferns have been found, as at Dargo and Bogong.

Up to the present no information regarding the occurrence of silicified wood in the Dargo district has been furnished, the wood there found being merely lignified. Thus, Reginald A. F. Murray, in his "Report on the Geological Survey of Portions of Dargo and Bogong,"[1] mentions gravels, sands and clays with impure lignites of Miocene age, resting on the bedrock and overlain by Miocene basalt (op. cit. p. 98). The same author (p. 102) says, "In a head of the Bundarrah, on the south-western margin of the basalt, are exposed beds of yellowish brown laminar clay containing fossil leaves"; and again (p. 106), referring to the beds exposed on the Mayford Spur at Synnot's claim, he states that "here also are siliceous conglomerates and ferruginous bands containing fossil leaves."

Description of Fossil Wood.

Specimen A. *Eucalyptus* aff. *melliodora*, Cunningham.

This specimen is a slab of silicified wood measuring about 15 cm. × 9 cm. × 3 cm. It was presented to the Museum collection by Mr. G. S. Rees, of the Construction Branch of the Victorian Railways, and was obtained by Malcolm S. Moore, B.E., in 1915, from Bruthen, during the construction of the Orbost railway line. The following is a note on its occurrence kindly supplied by Mr. Moore at my request:—

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1 Prog. Rep. Geol. Surv. Vict., No. V., 1878, pp. 96-117.

"This fossil wood is found in the coarse gravel beds which overlie the limestone and finer drift sands, and which appear to mark the course of the creeks in late Tertiary times. They frequently form the resistant material which has determined the position of the ridges. The fossil wood occurs with pebbles of quartzite, milky quartz and various volcanic rocks. The wood is always rounded and waterworn, and appears to have been petrified in some deposit previous to the one in which it is now found. The pebbles come from rocks which form the hills northwards from Omeo. There is abundance of Yellow Box growing in these hills at present."[1]

The general appearance of this specimen of fossil wood is closely like that of Yellow Box (*Eucalyptus melliodora*). Sections were cut in three directions, microphotographs of which accompany these notes.

Annual rings.—These average about 2 mm. apart in the fossil. In the Yellow Box specimen before me they average about 2.5 mm. This difference might of course be due to dryness of soil in the case of the fossil specimen, and in any case there is always a large amount of variation even in individual examples.

Pores.—In the fossil specimen these are thin-walled and rather densely packed. In *E.melliodora* they are moderately thin-walled and slightly less densely packed. In *E.obliqua* (Messmate), the pores are large and more dispersed. In *E.hemiphloia* (Grey Box) and its variety, *albens* (White Box), the pores are very dense. In *E.regnans* (Mountain Ash Gum), the pores are large, and more widely dispersed than in the fossil specimen, and the walls are thicker. *E. Sieberiana* (Silver Top) shows a closely similar structure to the fossil in transverse section. In *E.macrorhyncha* (Victorian Stringy Bark) the pores are less numerous than in the fossil.

Tangential Section.—The cross sections of the medullary rays in the fossil as compared with *E. Sieberiana* are shorter and more irregularly curved and tapering, whilst it closely agrees with those in *E.melliodora*. In *E.regnans* the fibres are denser and the medullary rays more numerous.

Radial Section.—The bundles of cells forming the rays in the fossil wood are much coarser in structure than in *E.hemiphloia*, and are exactly similar to those in *E.melliodora*. In *E.leucoxylon* and *E.regnans* the rays are more closely arranged.

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1 This last statement was in reply to a question as to whether Yellow Box was found in the district.

Upon submitting microphotographs of the wood to Mr. R. T. Baker, of the Sydney Technological Museum, who is a recognised authority on this subject, I have received the following interesting notes :—

"The weathered surface rather favours a coarse-grained timber, but such is not brought out in the other three. Your placing it near *E.melliodora* is a very good one, although the walls of the pores are much thinner than my specimens, otherwise I think it will do. In tangential section the rays are rather too small for that species than in my sections, but the radial is satisfactory. The other nearest Eucalypt is *E.albens.*"

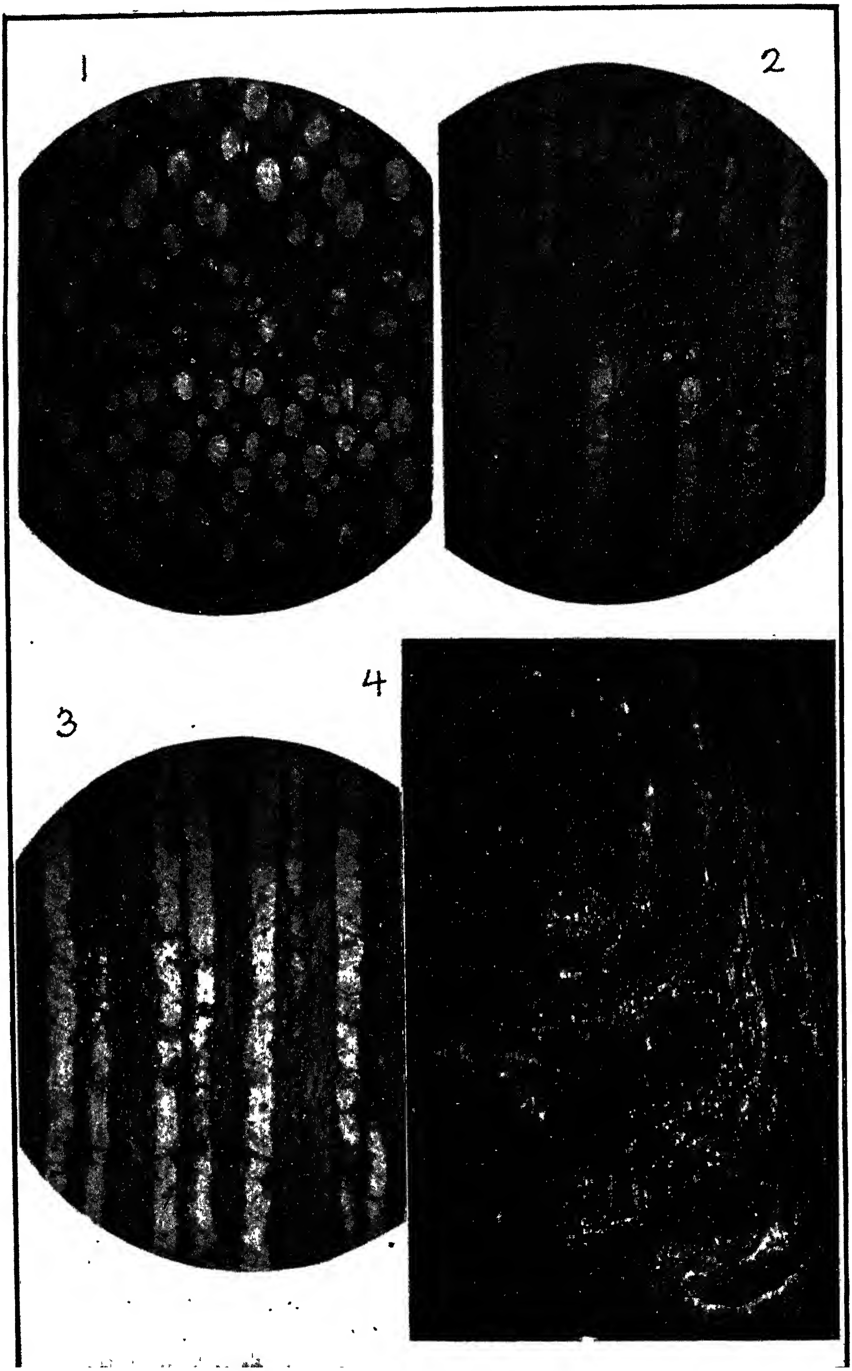
The Eucalypt, *E.albens* referred to is the White Box, sometimes regarded as a variety of *E.hemiphloia;* but as already pointed out, the pores are much denser in *E.hemiphloia*, and its rays are smaller and more finely cellular.

From the above comparison I think one is justified in placing specimen A nearest *E.melliodora*, but evidently an ancestral form of that species. During the time elapsing between the Upper Miocene or Lower Pliocene and the present (at a low estimate of about one and a-half to two million years), there was ample opportunity for a species like that of the genus *Eucalyptus* to vary. This is not a bold assumption, seeing that within the scope of very modern physiographic changes, variations in the genus have undoubtedly happened.

Specimen B. *Eucalyptus* sp. aff. *piperita*, Smith.

This specimen of fossil wood is of an entirely different character of Eucalypt to the preceding. It was obtained from the same gravel beds, but at Baker's Bight, Mallacoota Inlet, by Mr. P. H. Bond, who presented it to the Museum. The specimen measures about 31 cm. × 5 cm. × 5 cm. It is similarly silicified, though not so completely, and shows the burrows of a longicorn beetle traversing part of the wood; this burrow is about 6 mm. in diameter, and resembles those commonly found in such wood at the present time.

From a comparison of the wood structure this specimen comes nearest to *E.piperita* (White Stringy Bark). The radial section shows the same characters in having the compressed cells of the rays in perfectly straight series and of the same dimensions; while the marked fissile character of the liber cells is more like that species than *E.obliqua.* The latter species, moreover, has larger radial tubes, and the pitted structure of the walls of the vertical ducts or pores is more conspicuous.



F.C., Photo.

Tertiary Fossil Wood, Bruthen, Gippsland.

EXPLANATION OF PLATE X.

Fig. I.—Transverse section of silicified wood of *Eucalyptus* aff. *melliodora*, Cunningham. From the Tertiary gravels of Bruthen, Gippsland, × 13.

Fig. 2.—Radial section of ditto, × 13.

Fig. 3.—Tangential section of ditto, × 13.

Fig. 4.—Surface of weathered specimen of silicified wood (*E.* aff. *melliodora*) from Bruthen, Gippsland. Nat. size.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part I., 1918].

Art. IX.—*The Physiography of the Werribee River Area.*

By CHARLES FENNER, D.Sc.

[Read 11th July, 1918].

(With Plates XI. and XII., and 40 text figures).

(b) *The Faulting, its age and effects.*
- (i.) The Rowsley or Bacchus Marsh Fault.
- (ii.) The Greendale Fault.
- (iii.) Minor Faults.
- (iv.) Previously demonstrated Faults.
- (v.) Suggested Faults.
- (vi.) The Sunklands.
- (vii.) Final considerations as to Age.

(c) *The Newer Volcanic Sheet, and its effects.*

IX. Detailed Account of the Physiography.

(a) *Ranges and Hills.*
- (i.) The Main Divide.
- (ii.) The "Block Ranges."
  - (a) Blackwood and Lerderderg Ranges.
  - (b) Brisbane Ranges.
  - (c) The Ballan Plateau.
  - (d) The Gisborne Highlands.
- (iii.) Residual Hills.
  - (a) The You Yangs.
  - (b) The Anakies.
  - (c) Trig Hill, Bald Hill, etc.
  - (d) Mount Wilson.
- (iv.) Volcanic Hills.
  - (a) Wuid Kruirk.
  - (b) Mount Blackwood.
  - (c) Mount Bullengarook.
  - (d) Gisborne and its neighbours.
  - (e) The Anakies.
  - (f) Volcanic hills of the Lower Plains.
  - (g) Volcanic hills about Ballan.

(b) *Rivers and Valleys.*
- (i.) The Werribee Basin and its Divides.
- (ii.) The Werribee and it Tributaries.
- (iii.) Details of Individual Streams.
  - (a) Werribee River.
  - (b) Lerderderg River.
  - (c) Parwan and Yaloak Creeks.
  - (d) Pyke's Creek and its tributaries.
  - (e) Myrniong Creek.
  - (f) Korkuperrimul Creek.
  - (g) Goodman's Creek.
  - (h) Pyrete Creek.
  - (i) Djerriwarrh and Toolern Creeks.
- (iv.) Buried Rivers (pre Newer Basaltic).

(c) *Plains and Swamps.*
- (i.) Volcanic Plains.
- (ii.) Alluvial Plains.
- (iii.) The Bacchus Marsh Basin.

I.—Area dealt with.

The area dealt with in this paper is that part of Victoria drained by the River Werribee and its tributaries. The country that has been visited and examined includes also the water sheds separating the Werribee from its neighbour rivers on the north, east, and west, and it was found convenient, for the following out of certain features, to further carry the investigations southward to include the You Yangs and Anakies, and the eastern face of the Brisbane ranges. This embraces a total area of nearly 1500 square miles, and is set out on the map shown as Plate XI.

II.—General Considerations.

While the Werribee is one of the smaller rivers of the State, it is in many ways one of the most interesting. The great stretch of plain about the Lower Werribee was the scene of many of the incidents of the early dawn of Victorian history. These great plains, known as "Iramoo," by the aboriginals, were crossed by Flinders (1802), Grimes (1803), Hume and Hovell (1824), and here also some of the first extensive land surveys were carried out by John H. Wedge, the first surveyor of the State.

In contrast with these early-known volcanic plains, now comparatively well settled, and crossed by important roads and railways, we have in the northern parts a large unmapped area, an area of steep, thickly-timbered ranges, intersected by a maze of gullies, an area where roads and fences are rarely seen, and where the sole inhabitants are occasional prospectors or sawmillers. These unsettled uplands, consisting of steep, quartz-strewn ranges, form portion of the great general uplifted and dissected peneplain of Victoria. Discussion is entered into as to the probable period when this planation was accomplished, and its relation to other tertiary features—the faulting and the volcanic periods.

Midway in the area is the green oasis of Bacchus Marsh, with its neighbouring complex geological formations, and its puzzling

physiographic features; while an added interest to the whole area lies in the fact that several well-defined faults traverse the country and greatly influence the topography. The existence of certain of these faults will be demonstrated in this paper, and their great importance in the history and economy of the Werribee area, as well as their probable relationship to the general physiography of the State, will be dealt with.

The main part of the paper is of course occupied by a detailed description of each river, hill, and plain, as observed in the field. The structure and origin of each feature is considered. The "buried rivers" also provide material for a separate section, and the pre-basaltic drainage system has been partly reconstructed. The progressive physiography is then summed up in a "chronological column."

Research into the origin of the name of the river has revealed so much of interest in its varying nomenclature that it has been thought advisable to include mention of same, and this in turn involves some considerations as to early history and settlement. Finally, an effort has been made to correlate the present occupation of this area by man with the structural features and formations. In this section the various towns and villages in the Werribee area are considered in relation to their geographical situation. The influence of the main topographical features on roads, railways, water supply, etc., is also discussed.

III.—Previous Literature, Acknowledgements, etc.

While there has been little previous work done on the actual physiography of the Werribee or any part thereof, an enormous amount of material, geological and otherwise, has been published which has various bearings on same, and this has been utilised to the fullest extent possible.

(a.) Professor Skeats' University Geological Survey Party, 1915, which worked in connection with the Mines Department, devoted its time to the Blackwood parish, and especially to the neighbourhood of Greendale, in this area. The writer contributed a small paper on the physiography of the same, embracing the opinions of the party on the important "Greendale fault"; this has not been published, and has been, with the permission of Professor Skeats, largely embodied in this paper.

(b). The Lands Department courteously supplied copies of the numerous parish and county plans of the area, and these were

likewise utilized. The almost total absence of "features" from the parish plans greatly minimizes their value, and for part of the area dealt with, not even parish plans were available. Parts of the plan of County Bourke, for instance, remain to-day as they were first published, unfinished, many years ago, on the 1845-46 surveys.

(c). The geological formations underlying the surface features have necessarily been of prime importance, and the Quarter Sheets published by the Victorian Geological Survey have been liberally availed of. In addition, the writer has been kindly supplied by the Survey authorities with copies of the unpublished plans of Moorabool W., Moorabool E., Korweinguboora, Blackwood, Gorong and Darriwill. Further, he has been allowed to make tracings of unpublished quarter sheets 11 S.E. and S.W. The various reports of that department, including boring records, have also been utilized,

For all this, thanks are due to the Director, Mr. H. Herman, and his officers, especially Mr. W. Baragwanath, of the Ballarat Branch.

(d). The Military Survey of the Commonwealth has, fortunately, done a great deal of contouring work in this area. The writer has thus had the invaluable assistance of their published sheets, as well as access to all the original field notes of the surveyors, in which matter every assistance was kindly afforded by the officers of that branch; special thanks are due to the chief draughtsman, Lieut. Raisbeck.

Subsequent to the preparation of the paper, the Commonwealth Military Survey have published a contoured plan of the greater part of this area, on a scale of two miles to the inch. It is on sale as the Ballan-Meredith-Sunbury-Melbourne sheet, and reference to same would help to make clear many points in this paper that it was not possible to illustrate.

(e). The Railway Department has, during earlier years, accumulated much valuable information in the nature of trial railway surveys over various less-known parts of the area, and the writer was allowed to examine and make full notes from all these old surveys in their offices.

(f). In the matter of rainfall and water conservation, the Commonwealth Meteorologist and the State Rivers and Water Supply Commission courteously complied with all requests for information made to them.

(g). Since this account of previous literature has developed into a series of grateful acknowledgments, the writer would here wish also to place on record his chief acknowledgment—to Professor Skeats, of the Melbourne University, who first suggested this river as a subject of study, and who has also afforded every encouragement, and helped to make available many of the sources of information mentioned above.

(h). To Mr. A. W. Steane, of Ballarat, thanks must also be recorded. Mr. Steane accompanied the writer on his wanderings for many weeks during vacations, and assisted to explore numerous hills and valleys in which his interest was not great, and provided also an easy and rapid means of travelling from place to place.

A full list of the references quoted in this paper will be found at the end. (Section XII).

IV.—History, Early Settlement, Nomenclature, etc.

From the point of view of settlement, the two portions of the Werribee basin—the extreme upper and the extreme lower parts—present a marked and interesting contrast. The wide, level basalt plains of the Lower Werribee were among the earliest settled portions of the State, while the thickly-timbered, deeply-gullied, quartz-strewn Ordovician ranges of the upper Werribee still remain to a large extent uncharted and unsurveyed.

To go right back to the early morning time of the history of Victoria, we find that on Saturday, May 1st, of the year 1802, Matthew Flinders landed on the low Western shore of Port Phillip, and walked across these plains to the highest peak of the You Yangs, which he called Station Peak; from there he observed the plains of the Lower Werribee—the first white man so to do. His log-book entry is of some physiographic interest: "Our way was over a low plain where the water appeared frequently to lodge; it was covered with small-bladed grass, but the soil was clayey and shallow." (ref. 59). It was just two years later that a second explorer traversed these plains, in the person of Mr. Charles Grimes, then Surveyor-General of New South Wales. Grimes was sent by Governor King in 1803 to walk round and survey the harbour of Port Phillip. During this survey, on Monday, 14th February, 1803, he made the first crossing of what is now the Werribee River. Beyond mentioning the crossing, he leaves us no observation of any value (ref. 58).

In 1824-5, Hume and Hovell, in their overland journey from Sydney, also crossed the river, and it would appear that they gave the stream a name. Bonwick records in his book of 1883 (ref. 58, p. 83): "Piercing the Dividing Range near Kilmore they reached the Plains, crossed the Arndell, now the Werribee, and camped at what the natives called Geelong." Labilliere (ref. 59, p. 196) says: "Hume speaks of a stream he calls the Tweed. . . . The Tweed was probably the Werribee or perhaps the Saltwater River."

Having now mentioned two possible original names of the Werribee River, we find ourselves in the midst of a most confused period, during which no less than seven names were applied to that river whose name is now so firmly established as the Werribee. While briefly following out this matter, we may also endeavour to arrive at the origin of the present name.

We pass on to the period about 1835-6, when settlement of the Port Phillip District really commenced. Then came John H. Wedge, the pioneer surveyor of Port Phillip; to this gentleman we owe most that we know of the early settlement of the lower Werribee. He crossed the river, then in flood, on Sunday, August 30th, 1835 (ref. 58), and records: "This river I have named the Peel." (This was on the day that Fawkner's party landed on the site of Melbourne.)

Just about this time, also, the name of the River Exe was given to the Werribee, while Hume and Hovell's "Arndell" had become "Ardnell," and had been transferred to the more northerly stream (later the Saltwater). Bonwick (ref. 58, p. 275) refers to a map published by Arrowsmith, in 1837, giving "a river flowing south to Hobson's Bay, as the Ardnell, now the Saltwater." He adds: "Across the Exe and the Ardnell are written the words: Extensive and beautiful downs, called Iramoo by the natives."

Major Mitchell, viewing the Bay from the top of Mount Macedon, on September 30th, 1836 (ref. 60), says: "I perceived distinctly the course of the Exe and Arundell Rivers." Mr. F. G. A. Barnard states, in a letter, that the Werribee is mentioned in Batman's account of his settlement of Port Phillip, and is called the Exe. Mr. Barnard also points out that this name is still perpetuated in the village of Exford, situated where the Toolam Toolern Creek enters the Werribee.

We have thus had our stream as the Peel, Tweed, Exe, and Arndell; from now on the names applied approximate more closely to the present one. In 1856, Bonwick (ref. 57) reproduced an old

map (undated) from the surveys of Wedge and others. On this the Werribee is shown, but not named, while the Saltwater is given two names; near the mouth it is named the Saltwater River; while higher up it is labelled "River Wearily."

By the courtesy of Mr. Saxton, of the Lands Department, the writer has been shown an interesting original map of part of the Harbour of Port Phillip by D'Arcy, July, 1837. This shows only the mouth of the Werribee, but it is clearly labelled "*River Weariby.*"

In 1838, in a map by Asst. Surveyor Smythe, the name is very distinctly lettered, and twice spelt "Weariby." It is believed by some that this name is the "Wearily" of the Saltwater transferred, and with the italic "l" of a previous map mistaken for a "b." Probably, however, the error was in the map reproduced by Bonwick, with an "l" replacing a "b."

Wedge published a good deal of description and some pictures from 1836 onwards, referring to the river as the "Peel or Weiribie River," and later, foregoing the name (Peel), which he had originally given, he refers to it as simply the "Weiribie." We thus see that within the first twenty years after its discovery, the river had been referred to as the Peel, Arndell (Ardnell, Arundell), Tweed, Exe, Weariby (Wearibie, Weiribie), and Werribee.

The present incomplete survey of this country has been referred to, and it is of interest, to note that in "Ham's Map of 1847," of which Mr. Barnard has kindly lent a tracing, the general outline of the Werribee and its tributaries is almost as well set out as it is at the present time.

From at least as early as 1847, and probably since 1840, the river has been consistently referred to as the Werribee River, although in 1866 Wedge wrote a letter to Bonwick, in which he refers to the Weiribie River.

While Bonwick mentions the changes which have taken place in names, and quotes the Wearily becoming Werribee as an instance, there is still a possibility that the name is of aboriginal origin. For instance, Wedge, who was the first settler on the river, and a man of parts, would hardly forego the prior name of "Peel," given by himself, to such a chance-grown name as Weariby. Further, in one of his sketches he refers to the Weiribie Yaloak; and since the latter is the aboriginal word for river, it naturally suggests that the first word was also native. Mr. G. Firth Scott (ref. 61, p. 94), says with reference to Hume and Hovell's journey: "Arriving

at a creek named by the blacks Werribee, and by Hume the Arndell, they refreshed themselves," etc. The writer believes for the above reasons, that the name was an aboriginal one. Whatever the mode of origin may have been, the rather euphonious title of "The Werribee," has now been firmly established.

There are many other interesting facts on record concerning the origin of place names in this area, but most of these are well known, as, for instance, the complex story of the naming of the You Yangs and the Anakies. While it is satisfactory to note the large percentage of aboriginal names preserved, some of these have locally fallen into disuse, although still recorded on the maps. For example, Wuid Kruirk, a dominating hill almost on the Divide, is known only by the name of Blue Mountain—a name too common to be of much value. Again, the Korjamumnip Creek is almost always referred to either as Doctor's or Pyke's Creek, while the Korkuperrimul in its lower part is called Lyell's Creek.

Four of the parallel northern tributaries of the Werribee are interesting in that their aboriginal-sounding names all commence in "Kor,"—i.e., Korweinguboora, Korjamumnip, Korobeit, and Korkuperrimul; this Mr. Saxton believes to be an imitative reference to the sound made by a frog, and used to denote water.

It is difficult to find any reliable translation of these or other aboriginal place names. The early settlers often mistook words of the blacks, and almost always finally came to mispronounce them. Then, on being written and introduced into maps, further changes of pronunciation would probably take place, and effectively disguise whatever original meaning the words may have had. Added to this there is a strong tendency among us, unfortunately, to anglicise the pronunciation of native names, and thus, for example, we find the pleasing name of Naracoorte (S.A.) pronounced and written "Narrowcourt."

Another peculiar feature is the giving of the same place name to two well separated places. Thus we have Steiglitz, a volcanic elevation on the open plains of Ballan, while the mining town of Steiglitz is in the heart of the heavily-timbered Brisbane ranges, about twenty-five miles away. Both places are named after an early settler (1838) von Steiglitz (ref. 62). More confusing and anomalous is the application of the name of "Mount Blackwood," long given to the volcano north-west of Bacchus Marsh, to the mining town seven miles away, in the *valley* of the Lerderderg River. There is very little communication between the two places, and their postal services come from quite different directions.

The Lerderderg River also presents a problem of nomenclature, It is believed by some to be aboriginal, and to signify a "broken reed." Others state that the name was given by Messrs. Bacchus and Hepburn, who, when exploring in these wilder parts, were constantly humming certain minstrel refrains, then "all the rage" in London. Thus, it is stated, we get the "Jim Crow," a creek near Daylesford, and the "La-di-dah"—from two of the better known refrains. This word La-di-dah, on being printed on maps, was given (it is said) the dignity of an improved spelling, which led to our present "Lerderderg."

The late Mr. C. Crisp, of Bacchus Marsh, a well-known authority on the history of that district, published a brief account of Bacchus Marsh in 1891; therein he mentions the Lerderderg as being the camping place of Mr. Bacchus, junr., in 1838, and states that the river was then called Lardedairk by the natives. This account of the origin of the name seems the most probable one.

It will be seen that the gathering of reliable accounts of the origin of place names is attended by much difficulty. An effort has been made in this section to bring together, as briefly as possible, the most interesting and most reliable instances. Kind assistance in the collection of historical facts was given by Mr. A. W. Greig, Secretary of the Historical Society of Victoria. and by Mr. Saxton, of the Lands Department.

V.—Rainfall and Water Supply.

It has been found possible under this head to make some attempt at quantitative work. By the courtesy of various officials, records of rainfall, evaporation, run-off, sediment carried, etc., have been collected.

It may be advanced as an apology that the records are few, and do not extend over a length of years. Still it is possible to make estimates from the material in hand, and this has been done. It will at any rate serve as a beginning with which future workers in this area may make comparisons.

(a) *Rainfall.*—This as supplied by the Commonwealth Meteorologist from sixteen selected stations, in or near the Werribee basin, is set out in tabular form as follows. The stations are placed in order from maximum to minimum. They are the records for the past ten years, and include the very wet year of 1911, with more than 12 in. over the average, as well as the dry years of 1908 and 1914.

RAINFALL IN THE WERRIBEE AREA—(10 YEARS, 1905–1914).

	Barkstead	Blackwood	Riddell's Creek	Bullengarook	Ballan	Bolinda	Gisborne	Sunbury	Myrniong	Bacchus Marsh	Keilor	Werribee	Little River	Mt. Rothwell	Mt. Cotterill	Melton	Yearly Average
1905 ...	...	38.40	22.82	24.15	24.26	...	...	23.62	22.51	22.26	22.69	21.51	17.39	20.66	...	18.79	... 23.25
1906 ...	...	48.26	30.70	...	28.98	...	..	23.22	23.88	21.97	20.36	19.11	16.32	17.45	...	18.78	... 24.46
1907 ...	...	33.01	...	...	21 14	.	22.47	19.03	16.96	18.75	17.76	16.78	17.60	17.48	16.97	17.43	... 19.61
1908 ...	...	26.65	...	16.33	16.61	15.69	20.10	13.36	12.49	12.92	12.78	13.58	...	13.31	11.16	11.52	... 15.11
1909 ...	46.61	46.57	29.88	28.20	26.74		29.58	22.32	25.20	21 23	20.60	20.93	21.19	22.37	18.21	...	... 27.11
1910 ...	39.41	39.67	26.86	28.74	24.97	26.49	27.23	22.61	22.31	21.65	20.34	20.53	19.63	17.89	19.13	16.20	... 24.60
1911 ...	47.04	50.04	40.54	39.38	37.84	36.79	...	37.04	32.78	29.23	28.52	26.48	27.05	26.13	27.20	...	... 34.71
1912 ..	...	31.39	21.81	20.64	23.47	22.11	...	21.00	17.48	15 78	18.24	16.08	15.53	13.83	14.65	10.60	... 18.82
1913 ...	...	37.54	26.49	...	31.37	24.91	...	22.68	19.39	18.25	17.86	17.35	15.19	14.77	15.94	15.56	... 21.33
1914 ...	23 72	22.62	19.92	...	16.56	...	...	20.09	15.55	14.60	16.03	12.82	11.25	12 36	13.56	13.54	... 16.35
Average	39.19	37.41	27.37	26.24	25.19	25.19	24.84	22.49	20.85	19.66	19.51	18.61	17.90	17.62	17.10	15.30	
Maximum	47.04	50.04	40.54	39.38	37.84	36.79	...	37.04	32.78	29.23	28.52	26.48	27.05	26.13	27.20	18.79	
Minimum	23.72	22.62	19.92	16.33	16.56	15.69	...	13.36	12.49	12.92	12.78	12.82	11.25	12.36	11.16	10.60	

This table shows in an interesting way how the various factors operating at any one locality remain uniform in their results throughout all years. As has been stated, the stations are arranged in order, from that with the greatest average fall for the ten years, to that with the lowest. The years of maximum and minimum rainfall show very nearly the same gradient.

The average rainfall for the Werribee and Saltwater valleys, published by Gregory, from figures supplied by Mr. Barrachi, is 27 in. (ref. 20).

The Werribee average, however, must be much lower than this, as the figures of the above table are those of a representative ten years, and give an average of 22.5 in. The Commonwealth Meteorologist, treating the area broadly, in his chart of Victorian rainfall, divides the area into zones practically parallel with the coast:—

(1) The mountain area with a rainfall 30 in.—40 in.; (2) an intermediate belt 20 in.—30 in.; and (3) a coastal belt with a rainfall of 10 in.—20 in.

This is not the whole truth, however, as certain local differences occur, and an endeavour is made to bring out these points by means of the diagram shown in Fig. 1.

Since there is an undoubted lowering of the rainfall from the Divide to the sea, the chief factors must be (1) height above the sea of the station selected, and (2) nearness to the main ranges. The two factors are closely parallel, but not quite so. Selecting these two factors, the diagram (Fig. 1) has been drawn thus:—(a) The sixteen stations are arranged at even intervals with vertical lines drawn to graphically represent the amount of rainfall; (b) In the same order, the stations are again similarly arranged, the vertical lines now representing, inversely, the nearness to the Main Divide, measured as distance from the river mouth; (c) in the third case the vertical lines represent the heights above sea level of the various stations. It was thought that, if these were the only factors, the curves joining the tops of the three sets of lines would closely resemble one another, and that any irregularity in the second curve should be compensated for in the third. This proves to be the case, with one or two interesting exceptions.

(a) It is clearly suggested by the diagram that the amount of rain received is closely proportionate to the nearness to the Main Divide. The rain-bearing winds travel across the area mainly from the west and north-west, proceeding from the higher to the

lower portions with a gradually decreasing rainfall. The third column shows that three stations—Riddell's Creek, Bolinda Vale and Sunbury—stand at lower levels than their rainfall would suggest, but all three lie in valleys considerably lower than their immediate surroundings.

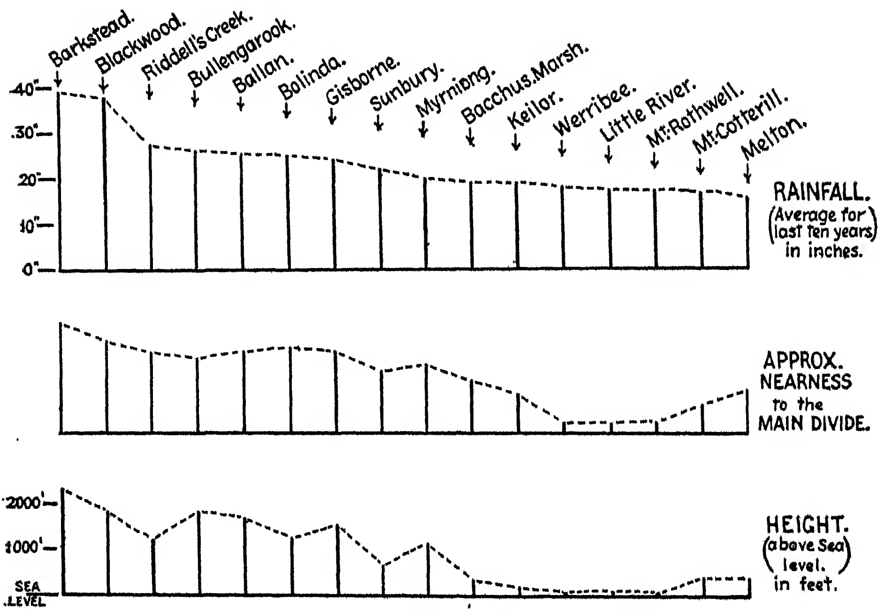


Fig. 1.—Diagram, showing comparison between the average rainfalls of various places in the area, with their heights above sea-level and distances from the sea.

The second irregularity shown is that of Melton and Mt. Cotterill, both of which have lower averages than would be expected. This may be due to the fact that the four preceding stations in the diagram—all nearer the coast—have their averages raised by coastal showers, which do not reach as far inland as Melton and Mt. Cotterill; while the western and north-western rain-bearing winds, which determine the rainfall of the area as a whole, have lost most of their moisture before reaching this belt.

(b) It may be, also, that these westerly and north-westerly winds, descending abruptly from the Ballarat plateau (average elevation over 1300 ft.) to the Lower Werribee plains (average elevation under 500 ft.), and thus suddenly becoming more compressed, and therefore warmer, are less ready to part with their remaining burden

of moisture; this sudden change in level takes place along an almost north-south line, referred to in this paper as the Rowsley or Bacchus Marsh scarp.

An interesting and independent corroboration of this point is afforded by the observations of Mr. R. Dugdale, of Bacchus Marsh. Mr. Dugdale has a very extensive knowledge of the whole of the area, from the point of view of land values, and informs the writer that local land buyers have long recognised a "dry belt" passing from a little east of Anakie through Nerowie, Mt. Cotterill, and Melton, almost parallel to the coast. This is a matter of economic interest, and the explanation of this dry belt appears to be as stated above.

(b) *Evaporation.*—Mr. H. C. Wilson, Manager of the Government Research Farm, supplies the following records of evaporation from a free water surface, taken at that farm, near the town of Werribee:—

Year		Rainfall		Evaporation
1913	-	16.43 inches	-	46.43 inches
1914	-	13.24 ,,	-	50.54 ,,
1915	-	15.55 ,,	-	51.75 ,,

For the three summer months of the former two years, the average monthly evaporation was as much as 7.11 inches, while for the winter periods the average was 1.44 inches. During the same period the average daily amount of "bright sunlight" for the year was 5.2 hours. For the three winter months the daily average was 4.0 hours, and for the summer period 7.6 hours per day.

It will thus be seen that evaporation is probably an unusually predominant factor in the disposal of the rainfall in these wide volcanic plains of the lower Werribee. The soil is generally somewhat clayey, and except after a very dry period when the soil cracks are widely opened, the percolation would be small, similarly the drainage is poor, swamps are common, and the run-off would be comparatively low. With the dry conditions, and the level nature of these plains, irrigation is naturally suggested, and we find that two of the most important farms of the State (the Government Research Farm and the Metropolitan Board Farm) are situated here. Both these farms are on a large triangular patch of river-built material, the soil of which is largely basaltic in origin, although much more sandy and porous than if wholly basaltic.

(c) *Run-off, etc.*—It is probably in the steep, wooded ranges of the upper part of the basin that the maximum run-off occurs. The contributing factors there are (1) steepness of the valley sides, (2) fairly impervious nature of the rock, and (3) the higher average rainfall. Percolation is probably at a maximum where the sandstones of the permo-carboniferous period outcrop, as these are very porous, and much fractured and faulted. They provide good, but not permanent springs.

In the figures published by the State Rivers and Water Supply Commission (River Gaugings, 1905, p. 7, et. seq.), it is shown that peculiar anomalies exist with regard to the percentage of run-off of Victorian Rivers, and also that very great variations occur. From the table showing the maximum and minimum annual discharges for the whole period, covered by their gaugings, it appears that the average maximum discharge is 31.5% of the total rainfall, while the average minimum is 7.9%.

We may compare with these the following figures for the Werribee and its tributaries:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Pyke's Creek near Ballan	1909	37 in.	34,170 acre-ft.	34%
	1912	36 in.	3,490 acre-ft.	4%

This great variation in the amount of run-off must be due to the different distribution of the fall throughout the years mentioned. The Werribee River, at the mouth of the Gorge, shows similar variations, with an unusually high percentage discharge in 1909:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Werribee River near the Gorge	1909	30 in.	73,970 acre-ft.	40%
	1912	22 in.	14,450 acre-ft.	11%

The gaugings on the Lerderderg at Darley are incomplete, and do not show any evidence bearing on this matter. Those taken at the town of Werribee, not far from the mouth, should really approximate to the total annual run-off for the whole river basin. They are:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Werribee River at Werribee	1911	34 in.	179,920 acre-ft.	19%
	1912	19 in.	36,990 acre-ft.	7%

(d) *Water Storage.*—Since the figures in the last section are the only data available for the whole area, and since 1911 and 1912 were respectively very wet (34 in.), and very dry (19 in.), an approximation to the normal discharge might be taken from an average of the two, and would give us about 100,000 acre feet per annum.

As far as can be learnt, the following are the only tributes levied on the river at present:—

Pyke's Creek Reservoir: Capacity, 14,800 acre-feet.
Exford Reservoir: Capacity, 10,000 acre-feet.
Bacchus Marsh (Town): Domestic supply of town.
Werribee (Town): Domestic supply of town.

It is very evident that much more can be done in the way of water storage in this basin. Ballan, although situated on the Werribee, draws its supplies from a railway department reservoir on the upper Moorabool, a river also largely utilized by the Ballarat and Geelong Water Commissions. It seems remarkable that such a fine stream as the Lerderderg River—the dominant stream of the whole basin, and fed by excellent permanent springs in its upper branches, should so far not have been used for storage purposes. A small reservoir originally existed on the Lerderderg above the town of Blackwood, the water being wholly for mining purposes, but this dam was destroyed by a flood many years ago.

(e) *Sediment Carried.*—A series of tests of the amount of solids in suspension was made during seven representative months of 1890. (See River Gaugings, Vict., 1905 and 1912.) The results were:—

Date	Werribee River at Bacchus Marsh	Lerderderg River near Bacchus Marsh
December 8	.20 grains per gal.	1.18 grains per gal.
January 13	.63 ,, ,,	1.82 ,, ,,
February 10	.27 ,, ,,	1.85 ,, ,,
March 10	.36 ,, ,,	1.07 ,, ,,
April 13	.46 ,, ,,	.54 ,, ,,
May 12	1.83 ,, ,,	6.10 ,, ,,
June 15	2.65 ,, ,,	1.97 ,, ,,

These may fairly be taken to be the natural burden of the streams, uninfluenced by any mining operations. From a consideration of the figures, the writer has taken 2 grains per gallon as a fair average of the material carried in suspension. No account is taken of the material in solution. Applying this to a year for which the more complete data are available, the wet year

of 1911, we get an estimate of about 6250 tons of solid carried to the sea in that year—an average of about 12 tons per square mile. Probably more complete data will show that this estimate is below the truth.

If we compare these figures with those of the great and actively-eroding rivers in other parts of the world (Russell, "River Development"), we find that the Werribee is not doing very extensive eroding work. This is indicated by the following figures, showing the proportion between the weight of sediment carried and the weight of water :—

Rio Grande, 1 : 291.
Uraguay, 1 : 10,000.
Werribee, 1 : 35,000.

The figures on which this result is based are reliable, but, unfortunately, incomplete. In view of the comparatively high grades of the various streams of the Werribee, and the extensive dissection proceeding in the uplifted blocks, clearly shown in Fig. 30, the result seems very low.

It must be remembered, however, that the rainfall is comparatively poor, and spread over the greater part of the year. Since a river does most of its erosive work in flood time, and especially at maximum floods, this distribution of the rainfall must be a factor against high erosion. Further, the river is working largely in very resistant rocks—indurated palaeozoic sediments and almost undecomposed basalts. Probably the above ratio would be more comparable to that of streams of the same size, working under similar conditions; no figures for such comparisons were obtainable by the writer.

VI.—Introductory Survey of the Area.

In order to convey a preliminary general idea of the physiographic features of the area, we may imagine that we are enabled to take a bird's-eye view of the whole country-side. (c.f. Plate XI.) The general impression would be of an area of low relief, rising from the flat shores of Port Phillip Bay to a general level of about 2400 feet at the "Main Divide" of Victoria, some 50 miles northward.

Colour differences, due to the contrast between the heavily-timbered and the pastoral areas, would be apparent, and the winding southern and south-easterly rivers would be visible. Along these, narrow deeply cut gorges would be noted, apparently irregu-

lar in their distribution. With these colour differences as a basis, and in order to deal with the area in greater detail, we may differentiate the whole into five main topographic "blocks." These are set out in Fig. 2, and are called A, B, C, D, and E. (See also block diagram Fig 3.)

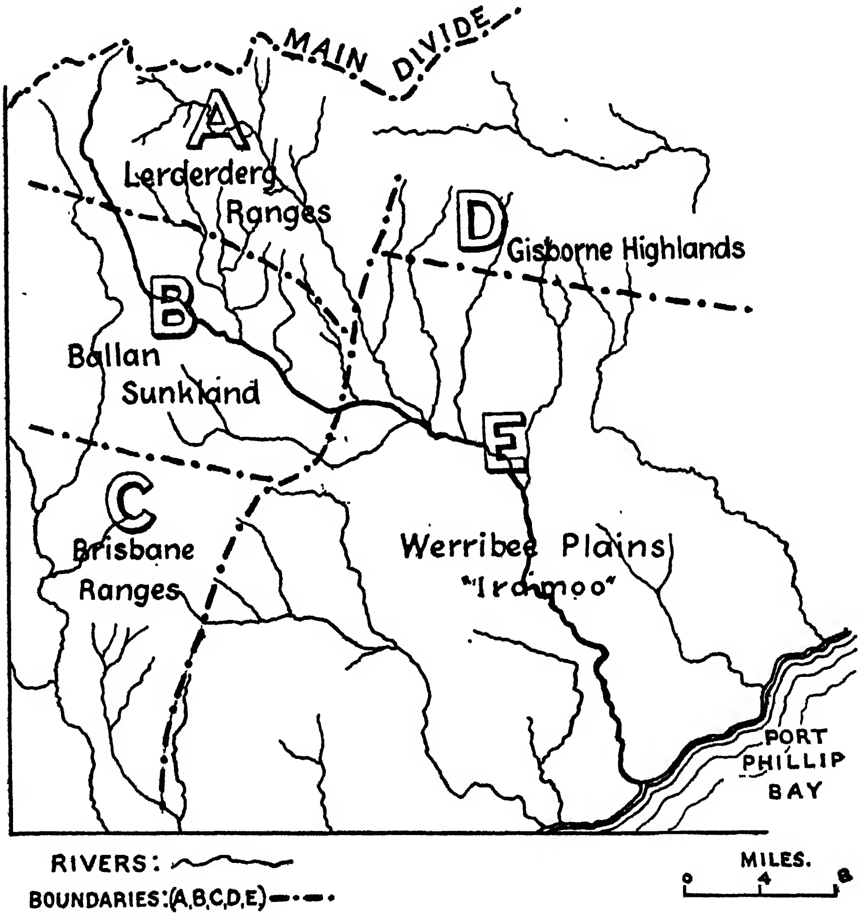


Fig. 2.—Subdivision of the area into five structural blocks for descriptive purposes (Section VI.).

(a). In the N.W. and S.W., blocks A and C stand out as great dark-coloured oblong masses of relatively high relief. Both are heavily timbered "Ordovician ranges," deeply scored into by river valleys, and they represent two separate portions of the great uplifted peneplain of Victoria.

On account of their numerous and steep valleys, both these areas present great difficulty for the building of roads or railways. In A the only occupations possible are those of gold miner and saw miller. In C this is also the case, except in the W. and S.W., where lava-flows and other features have so altered matters as to allow of grazing and agriculture with comparatively easy communication along N.S. lines.

(b). Block D, in the N.E., is also a relatively high mass, but lacks the unity of structure shown by both A and C. It is an elevated ordovician area, augmented in height by numerous volcanic hills and flows of lava. To the north of this is the Gisborne Creek valley, trending eastward, while the southern slopes contribute several streams (Pyrete, Djerriwarrh, Toolam Toolern Creeks, etc.) to the Werribee.

(c). The Central block, B, is the most interesting and complex of the five. It is an area of varied geological structure, as may be seen by reference to the geological map of Victoria. Not only so, but the rocks are such as to provide good soils, and the topography on the whole, allows for easy communications. While the surface of block A is wholly Ordovician, blocks C and D mainly Ordovician and Newer Volcanic, and block E almost wholly Newer Volcanic, this interesting area (block B), contains a very limited outcrop of lower Ordovician, abundant glacial sandstones, Older Volcanics, widespread fossiliferous Tertiaries, and broad sheets of Newer Volcanic. It is well settled, and mainly pastoral.

(d). The last block, E, constitutes the great level plains of the lower Werribee, almost wholly volcanic and lying at a considerably lower elevation than any of the other blocks. These plains are generally treeless, or sparsely timbered, and the land is everywhere occupied, mainly by graziers. In the south-west, at the mouth of the Werribee, is an important and closely settled irrigation area, while in the N.W., where the Werribee enters these plains, and where the important tributaries of the Korkuperrimul, Lerderderg, Parwan and Pyrete Creeks all meet together, is the somewhat remarkable and wonderfully fertile basin of Bacchus Marsh.

We should also note the great influence of the Newer Volcanic (late Tertiary) flows on Blocks B, D, and E. The old physiographic features of these areas were almost wholly blotted out by the lava flows, and a new set of streams has subsequently developed.

No single mountains stand out. The main divide is scarcely above the general level of the uplifted peneplain block on which

it lies. Several important volcanic cones, however, rise above this general level, and gain their impressiveness from the elevations on which they stand. First in importance is the dominating cone of Mt. Blackwood (2432 feet), standing on the south-eastern edge of the lifted block A. Mounts Bullengarook (2207 feet), and Gisborne (2105 feet), stand likewise on the high ridge of Block D. The most important height near the Main Divide is also volcanic; it is called Wuid Kruirk (more popularly Blue Mountain, 2800 feet), and is practically on the Divide. Two large masses, the Anakies (1350 feet) and the You Yangs (1134 feet), are on the lowest block, E. The You Yangs is a fine monadnock of granite, which still rises high above the lava flows of the plain; while the Anakies are partly granite, accompanied and dominated by a chain of high volcanic cones.

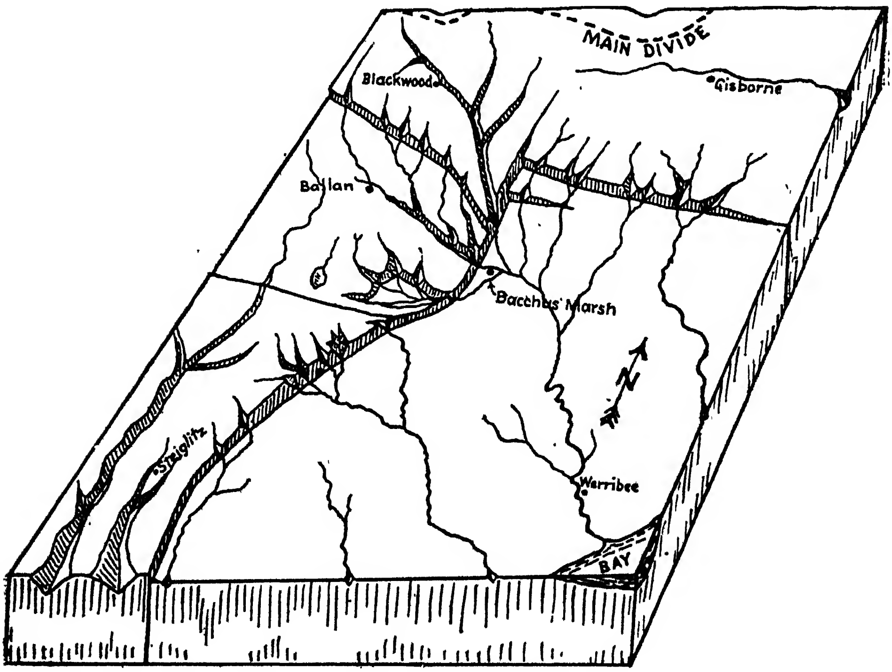


Fig. 3.—Block diagram of the area, looking from the south-east, to show relative positions of the main scarps and streams.

Fig. 3 has been drawn in order to give a rapid visual impression of these five great divisions and their relation to the Werribee and its tributaries. The figure is drawn as if viewed from the south-east.

The boundaries between these five divisions are not artificial, but natural. According to the belief of the writer, such boundaries are in all cases dominant fault lines. Detailed discussion of these important faults will be found in a later portion of the paper.

VII.—The Rocks of the Area.

Before entering upon the detailed account of hill and valley, we may with advantage discuss the nature of the various types of rock that occur, in so far as their nature and structure bear on the problems of physiography. For convenience we shall deal with the rocks in order of age:—

(a) Strongly folded sandstones, quartzites, and slates (Lower Ordovician).

(b) Granites and Granodiorites. (? Silurian and ? Devonian.)

(c) Glacial conglomerates and Sandstones. (Permo-carboniferous.)

(d) Older Basaltic lava flows. (Early to Middle Tertiary.)

(e) Gravels, sands and clays. (Middle Tertiary.)

(f) Newer Basaltic lava flows. (Later Tertiary.)

(g) Gravels, sands, soils, etc. (Post-Newer basaltic to Recent.)

(h) Dykes of various ages.

The following notes should be read in conjunction with the geological map of Victoria:—

(a) *Lower Ordovician.*—These rocks form, as far as is known, the bedrock of the whole area; they also outcrop over a very large part, forming practically the whole surface of Block A, most of C, and part of D. They consist of sandstones, quartzites, grits, and slates, intensely folded into anticlines and synclines; these strike almost due north, with variations of a few degrees east or west. They have been enormously eroded, since in the past they may have formed a land surface exposed to atmospheric erosion ever since the close of the far-away Lower Ordovician period.

In this connection, however, there are other possibilities that must not be overlooked. For instance, A. R. C. Selwyn, in his Notes on the Physical Geography, etc., of Victoria, 1866 (ref. 50, pp. 9, 10), draws attention to the possibility that the upper palaeozoic sediments of the Grampians area in the west, and the Mansfield-Mt. Wellington area in the east may once have extended in a "broken and undulating anticlinal arch," right across the intervening area. The accompanying diagram is but slightly altered from that published by Selwyn, and suggests the possibility referred

to (see Fig. 4). Except the smaller outlier of the Cathedral Range, in the Acheron Valley, no traces of these upper palaeozoic rocks have yet been recognised between the Grampians and the Mansfield area. Possibly, therefore, this intervening area was in those times

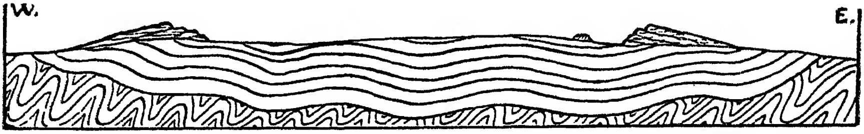


Fig. 4—Section to illustrate Selwyn's conception of the possible geological structure of Victoria as referred to in Section VIIa. This shows a geosyncline of Lower Palaeozoic rocks, with a broken anticlinal arch of Upper Palaeozoics. The underlying schists and gneisses have been added to those shown in Selwyn's diagram.

an elevated north-south area on the flanks of which these two widely-separated deposits may have been laid down in two distinct basins. The possibility that they once extended across the area under discussion is, however, worthy of consideration.

In the permo-carboniferous period vast sheets of glacial material were deposited on the Ordovician, and many remnants still remain; the protective effect of these beds must be borne in mind, but the glacial period itself is, in the foregoing paragraphs, regarded as an erosive period as far as the lower palaeozoic rocks are concerned, There does not appear to be any good reason for believing that the jurassic sediments of southern and south-western Victorian ever extended so far north as to affect the Werribee River area. Neither does it seem probable that the tertiary marine invasions ever extended over the present Ordovician uplands of the area dealt with in this paper.

Induration of these lower Ordovician rocks is in all cases so advanced that although, owing to the repeated folding, a variety of beds are exposed running in N.S. lines, little differential erosion is to be noted. In some cases in Block Aj (the Blackwood Ranges), north of Greendale wide quartzite bands may be followed along the ridges, in the formation of which they have no doubt played their part. Both E.W. and N.S. dykes occur; in places the former are very numerous.

Considerable faulting and jointing is noticeable and this has helped to give direction to various valleys. An interesting case is that of Back Creek, surveyed by the Melbourne University Survey Party in 1915. As shown in Fig 33, this stream is a fairly good example of a "drainage network" (ref. 32, p. 226). In places

igneous intrusions have turned these beds into hornfels or spotted slates, as exemplified in the Werribee Gorge area, but such alteration is not considerable.

The present total thickness of these beds is unknown. In the Bendigo gold field similar rocks were penetrated to a depth of 4600 feet, and proved of the same character throughout. We may sum up this most important series of rocks as being extremely and almost uniformly resistant to erosion. (Throughout this paper the term "Ordovician" refers to these lower Ordovician beds.)

(b) *Granites and Granodiorites.*—The nature of the plutonic intrusive masses, regarding their resistance to erosion, is well known. Granite forms the great mass of the You Yangs, whose highest point (Station Peak) still rises like a pyramid 1154 feet above sea level, and over 800 feet above the basalt and alluvial surrounding it. Towards the Anakies this granite is much worn down, and remains as low hills capped by huge residual tors. The only granodiorite exposed is a small area in the Werribee River, between Bacchus Marsh and Ballan. It assists in forming the rugged and precipitous "Werribee Gorge." On the surface it proves no more resistant than the rock (Ordovician), which it intrudes, and presents a fairly level surface of somewhat clayey and gritty soil.

(c) *Permo-Carboniferous.*—These rocks consist here of glacial conglomerates and sandstones, and present some differences in their powers of resisting erosion. They are for the most part either level bedded or gently dipping, and grade from very coarse conglomerates down to almost uniform fine sandstones. Their investigators state that rocks of this age had a variety of origin—glacial, fluvio-glacial, and probably lacustrine. In places the rocks are much compacted and indurated, as at the mouth of Werribee Gorge, where they occur in part as steep cliffs.

At other points we get friable sandstones, giving us rounded grassy hills, and wide U-shaped valleys, as in the lower Korkuperrimul (Lyell's Creek) and Bald Hill at Bacchus Marsh. The higher parts of Bald Hill, especially where the dip of the beds is most marked, present a very barren appearance, bare rocks being exposed over large areas. All the extensive outcrops of glacial are within the let-down Block B, except a few which have been similarly preserved in the N.W. corner of the relatively depressed block E. In the north of block B, we also get both types, the very hard rock giving up the high bluff near Glenpedder homestead, and the more friable material providing the pleasant rounded hills of

Greendale. The glacial deposits are estimated to have a maximum thickness of over 2000 feet (ref. 12, p. 269), and their base is exposed in many places. They are rarely stratified, are well jointed, and are intersected by numerous dykes, now largely decomposed. These dykes may be seen typically at the North quarry in Greendale, along Dales' Creek, and in the bye-wash cutting at Pyke's Creek reservoir.

The "glacial beds" are much less resistant than the Ordovician rocks on which they rest. Almost all trace of these has been denuded from the higher peneplaned surface of Block A, but the finding of undoubted large glaciated pebbles on the caps of the ridges north of Greendale, proves the previous existence of such deposits there. Mr. C. C. Brittlebank, has also kindly taken the writer to various small patches of undoubted glacial conglomerate, each a few square yards in extent, on the topmost ridges of the Lerderderg Ranges, about 1000 feet above the bed of the Lerderderg River (where it enters on the flats). It would appear from the evidence in this area that the glacial only survived the peneplanation where it had been faulted down, or else persisted, as stated above, in small patches, probably in old valley bottoms in the Ordovician.

(d) *Older Basaltic lava flows.*—This rock is generally described as of lower to middle tertiary in age. Messrs. Hall and Pritchard believed it to be "Eocene," but other geologists place it higher in the series, approximately "Miocene." The rock is usually a dense black basalt, and is mainly preserved in this area by faulting (Greendale and Bacchus Marsh), or faulting and warping (Maude). The question of the age of these lavas is briefly discussed in later portions of this paper.

Where it outcrops, it forms well rounded hills (Fig. 20), and provides excellent soils, which add much to the fertility of the localities mentioned. Beds of tuff, sometimes a bright red, occur in the series, and are to be well seen where the Myrniong-Greendale road crosses the Korobeit Creek. There appear to have been numerous flows, which in places may be seen tilted at various angles, especially along the right bank of the Lower Korkuperrimul, and at a point on the upper part of Robertson's Creek, a small tributary of the Lerderderg. The total thickness in this area is unknown, but similar flows occur at Flinders to a depth of 1300 feet. In their present decomposed state these rocks are easily eroded.

(e) *Middle Tertiary.*—This series includes a great variety of rock types all more or less easily eroded in places notably so. In

common with other tertiary deposits of Victoria, there is no consensus of opinion as to their age; Mr. F. Chapman classes them as Janjukian (ref. 12, p. 299). They occur mainly around Bacchus Marsh and in the Parwan valley, where they have been preserved by faulting, and at Maude. At Bacchus Marsh they are probably fluviatile, and consist of gravels, sands, clays, lignites, and ironstones.

They include valuable deposits of sands and clays (Dog Trap Gully), limestone (Coimadai), and fire clays (Darley). Their resistance to erosion is feeble, and the Parwan valley, as will be shown is an example of a small creek carving out a great valley in this material in a comparatively short time. Where the ironstones outcrop, as in cuttings on the Bacchus Marsh-Myrniong road, they appear to be somewhat more resistant, but the iron is rapidly leached out, and the clayey residue is soon carried away. Valleys in these rocks are marked by the frequent occurrence of land slips. Wilkinson and Daintree (ref. 56, Note 11) comment on the very easy erosion of these beds in the Parwan valley, and attribute it largely to the high percentage of soluble salts contained in the beds, chiefly sodium chloride and magnesium sulphate.

(f) *Newer Basaltic lava flows.*—This is the most widespread surface rock in the area. It covers almost the whole of block E and large parts of B and D, as a great sheet; tongues occur on blocks A and C. As already pointed out, it has largely obliterated the old drainage system and made the reading of the progressive physiography of the area a very difficult matter. These basalts are usually widely placed in age as "Pliocene to recent." The rock is a dense, well-crystallised basalt, tuffaceous beds occur rarely (there is a good exposure in a Werribee tributary at the foot of Mount Darriwill), and the very scoriaceous material is confined to the cones. It is well jointed, very platy in places (e.g., bed of Werribee below Ballan), and may be classed as very resistant to erosion.

This estimate of course refers to the rock as it occurs in most of its outcrops, viz., either quite fresh or with negligible decomposition. It forms on the whole a comparatively thin sheet mainly under 150 feet thick with a maximum depth of about 400 feet where filling old valleys.

It is of interest to note here Mr. C. C. Brittlebank's results, published in the Geological Magazine, 1900 ("Rate of erosion of some Victorian River valleys"), and following on a series of experiments conducted in the Werribee Gorge itself. Mr. Brittlebank places these rocks in the following order :—

1. Permo-carboniferous sandstones. (Most rapidly eroded.)
2. Granodiorite.
3. Ordovician slates and sand stones.
4. Newer Basalt (Most resistant.)

(g) *Gravels, sands, slays and soils.*—This is the latest series of rocks in the area, and their period of deposition extends from the close of the newer basaltic period up to the present day. They are naturally very loosely compacted, and present slight resistance to erosion; they are found throughout the whole area as small river flats, but are chiefly developed in blocks B, C, and E. We may classify them under three heads as regards origin:—

(i.) River Deposits.—Here we must place all the river flats throughout the area, and particularly the large triangular patch at the mouth of the Werribee River, as well as that surrounding the You Yangs.

(ii.) Fault aprons.—These like the last were deposited by stream action, but are differentiated in this classification on account of their origin as alluvial aprons, extending outwards from the bases of the various dominant scarps. They occur extensively along the west of block E, in the centre and west of block C, and in the north of block B. Their exact relationship to the scarps will be dealt with later.

(iii.) As a separate case we may consider the fertile and extensive flats of Bacchus Marsh. They constitute a considerable area of the most productive soils in the State, and in summer, when all the open country of the area is dry and brown, the green flats of Bacchus Marsh may generally be detected from any viewpoint in the district like an emerald set centrally between the Divide and the sea.

(h) *Dykes of various ages.*—These occur throughout the area intersecting the lower Ordovician, permo-carboniferous, and older basalts, but were not seen intruding into any later series, although dykes associated with the newer basalt must necessarily cut through the middle tertiary beds.

These dyke rocks have not been very closely examined petrologically, and for our purposes may be roughly divided into acid and basic types. The majority of those seen by the writer were east-west, and were apparently basic; in most cases they were of lower resisting power than the intruded rock, being marked on the surface by a hollow rather than by a ridge. North-south dykes also occur, a well-known one being in the Werribee Gorge. It is a highly resistant quartz-porphyry, and has noticeably restricted the width of the gorge at the point of intersection.

VIII—Dominant Physiographic Features.

Before entering upon the detailed description of hill and valley, we may first set out the three dominant tectonic occurrences which have governed and decided the present day physiography of this area, as well as of a large part of the State.

Firstly, a great "still-stand," during which a highly complete stage of peneplanation was reached.

Secondly, a widespread general uplift of this peneplaned area, gradual and differential. The differentially raised blocks separated along fairly sharp and straight lines, giving us fault scarps which still largely control the physiography.

Thirdly, after initiation of a new physiographic cycle, based largely no doubt on the older features of the peneplain, we had a great volcanic period when the newer basalt sheets wiped out many of the old river systems. A second period of faulting, with differential uplift, occurred. New river systems were initiated, and subsequent erosion has led to the formation of the varied series of hills and valleys, whose present day appearance now occupies our attention.

Each one of these three great features is important enough to warrant separate consideration, and since they are all excellently exemplified in the Werribee River area, we shall proceed to discuss them under the following heads:—

(a) The Peneplain, its date of completion.

(b) The Faulting, its age and effects.

(c) The Newer Volcanic Sheet, and its effects.

Other important happenings, such as the "older" period of vulcanicity, and the period of fluviatile or lacustrine deposition, are referred to in Section VII. and later sections. While these, too, played important parts in the production of the present physiographic features, the three above-mentioned happenings were found to be the dominant factors, and a separate section is therefore devoted to them.

(a) *The Peneplain, its date of completion.*

(i.) Introductory.— The writer enters on this question with the greatest trepidation, recognising the number and variety of conceptions that have already been published on the matter, and the difficult and sometimes contradictory nature of much of the evidence on which a decision must be based. In consideration, however, of close observation and critical examination of what appear to him to be fundamental points, he makes bold to advance the conclusions

arrived at from a study of the physiography of this particular district.

In this area the uplifted and dissected peneplain comprises blocks A. and C (see Fig. 2), the Blackwood and Lerderderg ranges (A), and the Brisbane ranges (C). In the other blocks it has been much more dissected or obscured by lava flows. From the summits of Mount Blackwood or of Wuid Kruirk (Blue Mountain) one may get an excellent view of the typical dissected peneplain. Equally as striking views may be obtained in eastern Victoria, but perhaps none so diagrammatically perfect.

The same peneplain uplifted and dissected has been recognised all over this State, in the highland area. New South Wales physiographers refer to three distinct peneplains in their highlands, but it is in the nature of things that *one*—the last—must be the dominant one at present, since in its formation all, or nearly all, pre-existing topographic features would naturally be destroyed. E. C. Andrews (ref. 3, p. 118) emphasises this fact in his paper on "Erosion and its Significance," viz., that the formation of one peneplain must mean the complete dismantlement of any older one, assuming the work to be done in areas of practically homogeneous rocks. W. B. Scott (Introduction to Geology), also says: "In the production of new topographic forms, old forms are more or less completely destroyed." Since, therefore, the last peneplain is the important one, and since there is no recorded proof in Victoria of traces of other peneplains, it is reasonable for us to consider our one peneplain alone.

(ii.) *The peneplain as an Australian feature.*—We may now push our investigations outward to cover a wider tract of country, and the following extracts from various writers are very suggestive of the possibility, long since recognised by E. C. Andrews (ref. 1), that an uplifted and dissected peneplain, perhaps the same peneplain, is the basis of the upland physiography of every State in the Commonwealth.

Victoria.—Every local writer on physiographic and allied matters recognises the existence of the dissected peneplain in this State. Individual opinions from various papers will be quoted later.

New South Wales.—E. C. Andrews, in common with all his fellow workers in that State, accepts the peneplain as the outstanding fact of our physiography. In reference 1, p. 421, he says: "Eastern Australia was a peneplain raised but little above sea

level towards the close of the miocene uprising (about pleistocene times), producing the great block faulting in the south-eastern knot."

Queensland.—J. V. Danes (ref. 15, p. 6, etc.), who chiefly worked in Queensland areas, believes, in common with Australian workers whom he quotes, that the peneplain extended from New Guinea to Tasmania and believes it "to have been divided into a large number of independent outletless basins with shallow lakes." (See also ref. 44.)

South Australia.—Rev. W. Howchin (ref. 31), the chief authority on the physiographic features of South Australia, states regarding the uplands of that State: "The old peneplain now stands at an elevation of 1500 feet, with rivers flowing mostly in juvenile gorges 300-500 feet deep." "The uplift probably coincided in the main with the Kosciusko epoch of New South Wales physiographers." (page 176).

Tasmania.—W. H. Twelvetrees (ref. 54, p. 162) states: "Since Pleistocene times the north-west part of Tasmania has apparently suffered an uplift relative to sea level, as evidenced by the existence of extensive elevated peneplains. Recent river systems have deeply dissected the area, and seamed it with profound gorges." L. Keith Ward (ref. 54a, pp. 6-18), describes an interesting portion of the dissected peneplain of north-western Tasmania.

Western Australia.—J. T. Jutson (ref. 35 p. 95) discusses all the available evidence, and concludes that the last great uplift of the broad plateau of Western Australia was pre-pleistocene and post-jurassic, probably early or late pliocene, while its reduction to a peneplain had taken place probably in early or middle tertiary times.

Northern Territory.—W. G. Woolnough (ref. 55, p. 45) states that the "Most striking feature (of the Territory) is the extent and uniformity of the plateau areas, 1000 feet or so above sea level. . . . This vast upland is a peneplain of the most perfect type and was formed by sub-aerial erosion at a time when the country stood much lower than it does at present. . . . It is trenched by numerous rivers, which have reached base-level for a long way up their valleys."

Papua.—J. E. Carne (ref. 11) does not deal specifically with the physiography, but mentions a "plateau deeply dissected by torrential streams," and further states that this plateau "in part consists of tertiary limestones of as late as pleistocene age."

(iii.) *Age of the Uplift.*—From a consideration of the above extracts and their accompanying reports, it seems justifiable to assume that the peneplanation was general over the whole continent, and that uplift of the peneplaned area to form the present highlands of Australia may possibly have taken place at very nearly the same geological period. It is generally agreed that this uplift dates somewhere between middle tertiary (miocene) and pleistocene times. The stratigraphical evidence on which the date of the completion of the peneplain is based mainly exists in Victoria. Therefore, having taken a brief survey of the extent of the general peneplanation and uplift we shall return to the problem of the date as far as it may be discovered in this south-eastern corner of Australia.

It is of course understood that we may have peneplains of various stages of completion yet each deserving of the title of peneplain. A very long period of still-stand of the land must be necessary in order to accomplish the perfect base-levelling of an area, but we appear to have had in Victoria a surface which closely approximated to that ideal. Immediately any uplift took place on the peneplain, rejuvenation of the streams would result, with dissection of the peneplain surface. The date of the commencement of uplift therefore marks the completion (or cessation) of the particular cycle of erosion which formed the peneplain.

The rocks which formed the surface of the peneplain in Victoria were for the greater part the lower and upper Ordovician, and the silurian rocks—all of which may be regarded as one rock type as far as erosion is concerned (see description of rocks, *supra*). The schists and gneisses of N.E. Victoria and the intruding granite masses also formed portion of the planed area, as did the softer level-bedded sandstones of the glacial period (Bacchus Marsh, Heathcote, etc.), the carboniferous sandstones and mudstones (Grampians, Mansfield, Mt. Wellington, etc.), and the devonian (Tabberabbera, Buchan, etc.) shales and limestones. Each of the three last named series of rocks now exists in limited areas only; they are mainly of a much lower order of resistance than the beds first mentioned, and are probably now largely preserved in patches where they may have occupied valleys and fault-troughs at the time of planation. In 1866, Selwyn (ref. 50) put forward the idea that the Mansfield-Grampians series of sandstones had once extended right over that surface of Victoria that now separates the two main occurrences. (See Section VIIa.) The numerous and scattered relics of our glacial sandstones suggest that they were formerly enormously greater in extent; there is no doubt they have

been mainly preserved by faulting in the Werribee area, and in all probability close examination would reveal like relations elsewhere.

Our Victorian peneplain, therefore, was for the most part composed of hard, folded slates, sandstones, and quartzites, with accompanying gneisses and granites, the less abundant later and softer rocks being preserved only in troughs and pockets.

At some date to be decided, this extensive level surface was subjected to great forces of uplift, which have ultimately at our present day resulted in the old peneplain level in eastern Victoria standing at 6000 feet above sea-level, in the Werribee area at 2000 feet or less, gently sloping westward until at the Glenelg River, in Western Victoria, it sinks below the younger beds of the "Murray Gulf."

There are two means whereby we might attempt to arrive at a decision as to the date of commencement of uplift:—

(a) Physiographic evidence, amount of erosion during and subsequent to uplift, fault evidence, etc.

(b) Palaeontological evidence—the selection of some bench mark with which we can correlate the beginning of uplift.

(o) *Physiographic evidence.*—Both methods above referred to have been availed of. Much use has been made of physiographic evidence in New South Wales, but it does not appear to lead to very reliable results. There are enormous variations in the amount of erosion accomplished during the same period at different points in this State.

(i.) At Dargo High Plains we have steep valleys 1500 feet in depth cut since the beginning of the uplift, and Mr. Herman (ref. 29 and 30) refers on page 339 to "3000 feet of vertical Cainozoic erosion" in that area.

(ii.) At Mount Buller (ref. 19, p. 396), the Howqua and Delatite have cut valleys nearly 4000 feet deep into similar hard slates and granites during the same period.

(iii.) In the Werribee area we have the Lerderderg, with its long and precipitous gorge, cut over 800 feet deep into very hard folded slates. This is much less than that accomplished in eastern Victoria, and shows how the factor of elevation affects the result.

(iv.) Meanwhile, we have the Werribee, above Bacchus Marsh, cutting a gorge about 700 feet deep in quite similar rocks subsequent to the Newer Basalt period, presumably a considerably shorter time.

(v.) Parallel with the Werribee is the small tributary of the Parwan excavating during the same time a great valley—much wider and deeper than that of the parent stream. (Figs. 24 and 30.) This result is due to the fact that the Parwan is working in softer rocks.

Since such enormous variations may be due to differences in elevation and rock-resistance, and since there are no means of knowing either factor quantitatively for any contrasted streams, this physiographic method does not seem to be of very great value in Victoria. Mr. Andrews has informed me, in a letter, that his later judgment and experience enable him to realize very fully the great variations in topography that may be wholly due to differences in the resistance to erosion that exist between different rock types.

There is another physiographic method of determining the date of uplift, and that is to fix the age of the fault scarps formed during such uplifts; the writer has followed this method with some success, as will be detailed later. (Sect. VIII., (b), (vii.)).

(b) *Palaeontological evidence*.—The second method, and the more reliable, is to make an effort at correlation with known fossiliferous beds. Here we have the difficulty of the lack of agreement as to the various ages of our well-known and much discussed Victorian tertiaries.

Dotted over the eastern Victorian highlands we find ridges and mountains standing at the general level of the old peneplain, capped and preserved by the remnants of basalt flows. These flows have been classed together as "Older Basalts," and correlated in time with older basaltic flows in the Melbourne and other areas. Somewhat loosely, and in a general way only, these occurrences of older volcanics have been correlated in age with one another, and with those of New South Wales and Queensland (ref. 45). As pointed out by Professor Skeats (ref. 47, pp. 199-201), in dealing with these older volcanic rocks, within the State of Victoria, the relationship of these rocks, with fossiliferous beds is weak, even where both are exposed together in one section. The weakness of the evidence is due to two factors:—(a) the stratigraphical relationships are not constant, the basalts being variously above, below, or interbedded with the fossiliferous beds, according to locality; (b) neither the correlation nor the precise geological ages of the associated fossiliferous beds are definitely agreed upon. Professor Skeats adds: "Many of the occurrences are separated by considerable distances from basalt whose age can be demonstrated and in these cases considerable doubt remains as to

whether they are correctly referred to the "Older Basalt," and if so, as to whether they are contemporaneous, or part of a series of eruptions extending over a long period of time."

The correlation of the ages of the Victorian basalts with those of New South Wales and Queensland seems to be even more a matter of conjecture. The main argument apparently is that where the general relations seem to point to basaltic lavas belonging to an older tertiary period, a correlation in age with the older basalts of Victoria is assumed, the grounds for such assumption being that since Eastern Australia appears to be a fairly compact tectonic unit, it is likely that the volcanic periods of the different States would be, in general, closely related in time.

It is unfortunate that much of the past physiographic work done in New South Wales has as far as time is concerned, been based on the assumption that the ages of the Victorian basalts and tertiaries were generally agreed on. The matter recurs in other parts of this paper, and is there discussed from the other points of view.

Having noted the above deficiencies in our knowledge of the ages of Victorian tertiary rocks, the writer feels the necessity for defining his beliefs in the matter. After a careful consideration of the evidence, therefore, it is here assumed, with the cautions already pointed out, that the older basalts of Greendale and Bacchus Marsh may be sufficiently closely correlated with those of Maude, Keilor, and Royal Park, and with the general mountain-capping basaltic remnants on our eastern highlands, to refer them to a period, called the Older Basalt period, and denoting a more or less extensive term of vulcanicity, which occurred at a time variously estimated as from lower to middle tertiary (Barwonian). This divergence of opinion as to age is largely due to the uncertainty that exists regarding the age of our fossiliferous tertiaries.

If these older basalt flows of our eastern highlands had been poured out while the area was still of somewhat high relief—i.e., some time before complete peneplanation—they would scarcely have been preserved to-day as we now find them. Moreover the valleys which these basalt flows have filled and preserved have been investigated in some places and prove to be of mature types. The fact that these basalts in eastern Victoria lie at, or a little above, peneplain level, appears to show that there could not have been a very long interval between uplift of the peneplain and the extrusion of the basalt. Otherwise we should expect to find these lavas, where preserved, somewhat below the general peneplain level. (See also Hart, ref. 22, p. 256.)

This leads to the conclusion that the completion of the peneplain (the commencement of the uplift), must have been very close in time to the extrusion of the older basalts. R. A. Daly (ref. 14, p. 193, etc.), suggests that lava flows tend to *follow* the initiation of movements of uplift and instances the pliocene and postpliocene basaltic sheets of Syria, Great Basin (U.S.A.), Idaho and Iceland.

We shall assume that the older basalt flows were closely associated in time with the first uplift of the great planed blocks that form our Victorian highlands.

Now the older basalts are closely associated with richly fossiliferous beds:—

(1) They overlie the plant-bearing deep leads of the Dargo High Plains, etc.

(2) They underlie the thick "Cinnamon and Laurel" leaf beds at Bacchus Marsh and Parwan.

(3) They underlie the rich marine beds at Royal Park and Keilor (Melbourne).

(4) They are interbedded with marine limestones at Maude, and other places in the lower Moorabool.

Unfortunately in all these cases they are associated with the beds concerning which essential differences of opinion exist between our palaeontologists. It is agreed, however, that these deposits are mainly of middle to lower tertiary age; eocene (Hall and Pritchard, Tate and Dennant), or miocene (McCoy, Chapman, Gregory, Newton, etc.). Following this line of argument, the initiation of the great uplift would certainly not be younger than, say, Miocene. The chain has many weak links but under present circumstances is as near as we can approach to the truth.

Moreover, since the writing of the preceding argument some few months ago, two very interesting cases of strong corroborative evidence have come to light—one of them following on personal observations in the field, and the other published by Mr. F. Chapman. These will be referred to later.

In New South Wales the general opinion (Sussmilch, Geology of N.S.W.), seems to be that a great epeirogenic uplift took place, and "ushered in the Tertiary period." Then followed the older basalts and a cycle of erosion which formed the "Great East Australian Peneplain." Then a small uplift, followed by the outpouring of the newer basalts, and, finally, in what is called the "Kosciusko epoch," another great epeirogenic uplift, with block faulting, and immediately followed by the Pleistocene period (ref. 48, pp. 208 et seq.).

Andrews (ref. 1, p. 457) believes that the peneplanation in New South Wales, by analogy with that of Western America, may be assigned to tertiary times, and that the block faulting, plateau forming, and gorge carving may be assigned to the Ozarkian or Sierran (Pleistocene age).

(c) *Previous work on this matter in Victoria.*—It will be of advantage to examine the results arrived at concerning this matter by various independent workers in Victoria.

J. T. Jutson (ref. 33) deals with the Nillumbik peneplain, near Melbourne, a less uplifted portion of the great peneplain. He proves that the uplift there was differential and gradual, and believes that the older basalt of Kangaroo Grounds was erupted prior to the completion of the peneplain.

T. S. Hart (ref. 22, p. 272) believes our highlands "to be due to the unequal block elevation of a Mesozoic or early Tertiary peneplain, with subsequent extensive modification by denudation and volcanic activity."

D. J. Mahony (ref. 39, p. 377) speaks of our highlands as "a dissected peneplain," differentially uplifted. He postulates a long pre-Miocene period of quiescence followed by a great uplift, with vertical movement. He believes the older basalts to be associated with the first great period of earth movements, while the newer basalts "mark the close of the last great movement that elevated our Victorian Kainozoics."

Professor David (ref. 12, p. 287) sums up thus: "In either very late Pliocene, or very early Pleistocene time, the earth's crust, in the Australian and New Guinea region, was subjected to considerable diastrophism. The eastern periphery of Australia, including Tasmania, was warped up to altitudes of over 3000 feet above the sea."

Professor Skeats (ref. 47, pp. 188-189) suggests that the first peneplain uplift in Victoria was post Mid-Kainozoic, followed by later uplift and dissection, with consequent formation of another, *the* peneplain; the present surface features being the result of a still later uplift and consequent erosion. Professor Skeats also suggests (B.A.A.S., 1914, p. 360), a post mid-tertiary age for the "succession of elevatory movements of the plateau type," that have affected the Omeo district in eastern Victoria.

N. R. Junner (ref. 36), who also investigated the Nillumbik peneplain, believed the uplift to be Kalimnan, and to have been differential and gradual, without faulting in that area.

Jas. Stirling (ref. 51), writing thirty years ago, on an area in our Eastern Highlands, says: "That a vast tableland existed in Miocene times, stretching from Mt. Buller to Mt. Kosciusko, and of which the Omeo plains and Maneroo tablelands are visible remnants, seems to be abundantly proved. Powerful erosion has subsequently excavated deep valleys, which now break up these once extensive tablelands." Mr. Stirling was aware of the gradual uprise of the land as a factor in deepening the rivers, but he wrote of these facts at a time when our present physiographic terminology was scarcely known.

The question appears to gain in complexity as one studies the individual viewpoints of other investigators. For reasons already stated, the writer can see definite proof of only *one* great peneplanation in this State. Two or three scattered monadnocks, of somewhat similar height, can hardly be called in as evidence of a prior planation. They would perhaps owe their existence to superior resistance, and if plutonic, may not even have been uncovered at the conclusion of a previous base-levelling of the area.

Various writers referred to have demonstrated, and all agreed, that uplift was very gradual. Undoubtedly also there were periods of no movement, and in some localities periods of depression. Jas. Stirling (ref. 51) refers to thick terrace alluvials on the sides of the Tambo, high above the present level of the river; these bear witness to a more or less sustained period of still-stand, with consequent deposition. Similar terraces occur in the Goulburn, and the writer has examined relics of such terraces high up along the valley of the Lerderderg, where three series occur. Depression must also have occurred in parts of the State, as pointed out by D. J. Mahony (ref. 39, p. 377), in order to allow of the deposition of our marine Kainozoics. The great depth of tertiaries in the Sorrento bore (1696 feet) and the still more unexpected result at Portland, where 2265 feet of the tertiaries were penetrated, without reaching the bottom of the series, (ref. 40), prove extensive kainozoic depression. Such depressions were to some extent local, and occurred in conjunction with the progressive uplift of the neighbouring highlands.

(d) *Conclusions.*—Regarding the completion of peneplanation of a large resistant rock area as an event of at least a similar order of magnitude, in time, as a geological period of sedimentation, and possibly of rarer occurrence, the writer's present conclusion is that the peneplain represented by the present level crests of our Vic-

torian highlands—grading from 6000 feet above sea level in the east, to a few hundred feet in the west—was completed about the time of the older basalts (? Miocene), when the first important uplift took place. This may have gradually continued, with intermissions, but in a period subsequent to or contemporaneous with the newer basaltic eruptions, there was a second considerable movement of uplift.

This last movement would seem to coincide with the later dates (Kalimnan and Pleistocene) arrived at by the majority of previous writers.

The proofs produced in the next section, regarding the ages of the faults in the area under discussion, bear closely on this question.

(b) *The faulting, its age and effects.*

On the occasion of the reading of a paper before the Royal Society of Victoria in 1913 (ref. 19), in which extensive block faulting was postulated on purely physiographic grounds, the then President of the Society tendered to the writer a kindly caution against accepting large faults in any area without abundant proofs, especially those of a stratigraphical nature. This advice has tended to make him very cautious and critical in his working out of the faults of the Werribee River area.

Experience in the field, however, combined with reading on this matter, and consultation of maps and sections from various closely-mapped areas in this country and others, leads to the conclusion that, in addition to the few dominating faults which will be clearly demonstrated in this paper, abundant other faults, of less extensive movement, occur. The conviction is here expressed that block B, and especially the complex Bacchus Marsh area, will be proved on more thorough knowledge to be a mosaic of small faulted blocks.

New South Wales has ever taken the lead in Australian physiographic questions, and there the most able exponents, David, Andrews, Taylor, and others, abundantly demonstrate block faulting as an important feature.

Mr. Andrews, however, among much generous advice tendered to the writer by letter, states that his more mature views are that "Epeirogenic uplifts and differential erosion have been the key to the tertiary history of Eastern Australia, with block faulting as a subordinate feature."

In his interesting Physiography of Western Australia (ref. 35), Jutson describes the great Darling fault scarp, extending for 200 miles, as well as others of lesser importance. In South Australia we have the accepted rift valley of Lake Torrens, and the definite block-faulting of the Mt. Lofty ranges; while between Victoria and Tasmania is the great and generally accepted sunkland of Bass Strait.

In Victoria, also, T. S. Hart, commencing with the diagrammatic example of block faulting in the Grampians of the west, has proved the same features to continue eastward along the Divide as far as Ballarat (refs. 22, 23). It is unfortunate that the Grampians themselves have not been more closely and critically studied from the physiographic viewpoint.

Jutson (ref. 33), on carefully collected physiographic evidence, has demonstrated certain faults in the middle Yarra area, and has suggested the presence of others. Morris (ref. 38), in his paper on the Geology of the Lilydale area, expresses his belief that the geological evidence there points to the existence of important faults.

The mining fields of the State—Ballarat, Bendigo, Steiglitz, Blackwood, and Wonthaggi, etc.—show abundant faulting in their detailed mine plans and sections, while to miners in our fields strike faults ("Slides," etc.), and dip faults ("Cross courses") are very well known features.

The relief of the Werribee River area has been almost wholly decided by differentially uplifted blocks of country (as already mentioned), separated by well-defined scarps. Of these the two most important may be called :—(a) the Rowsley or Bacchus Marsh scarp, and (b) the Greendale scarp.

The faults (demonstrated or suggested) referred to in the following pages are set out in Fig. 5, where they are given alphabetical symbols for simplicity of reference. They will be dealt with in the following order :—

(i.) The Rowsley or Bacchus Marsh Fault.
(ii.) The Greendale Fault.
(iii.) Minor Faults.
(iv.) Previously demonstrated faults.
(v.) Suggested fault.
(vi.) The Sunklands.
(vii.) Final conclusions as to age.

(i.) *The Rowsley, or Bacchus Marsh, Fault.* (see a, in Fig, 5).—One of the least impressive portions of the scarp which marks this

important line is perhaps its most widely-known part, namely, the basalt-covered slope lying westward from Bacchus Marsh, and up which the Ballarat-Melbourne railway line ascends by a horseshoe-shaped loop, 6 miles in length (see Plate XI.). It has been observed by practically all later Australian geologists, and a few references thereto are to be found in current literature, but excepting the observations by Mr. Hart (ref. 22), no detailed work has been done on it.

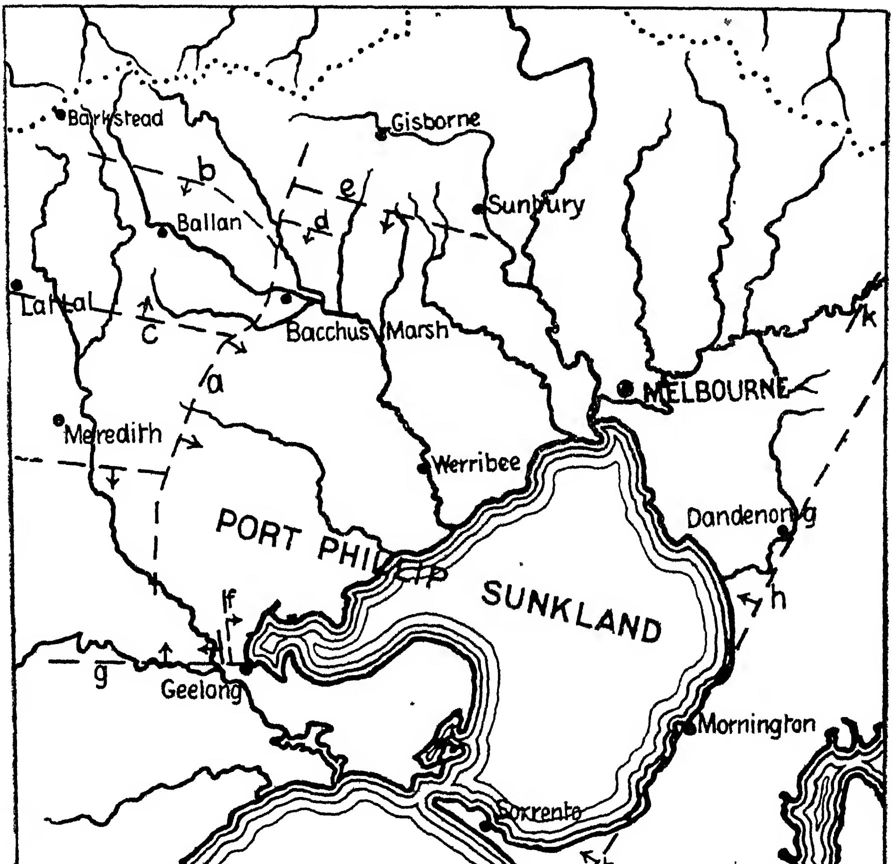


Fig. 5.—Map of the surroundings of Port Phillip Bay, showing the positions of the chief demonstrated, suggested, or generally accepted faults. These are shown by broken lines, and lettered alphabetically as per context (Section VIIIb). The directions of downthrow are suggested by arrows.

The scarp is really about thirty miles long, and is economically and topographically the most interesting feature of the whole area under discussion. It acts as a barrier between the lower early-settled plains of the lower Werribee and the important agricultural and mining centres of Ballan, Ballarat, Blackwood, etc. It presents a difficult problem to the engineer, and while the railway has ascended by an extended loop, the climb is still difficult, and extra power is required to carry trains up the stiff rise of 1300 feet from Bacchus Marsh to Ballan. The main road also takes a devious course, along the valley sides, but it, too, still presents sustained and difficult grades to the traveller.

The following opinions have been advanced regarding this scarp :—

(i.) Professor J. W. Gregory (ref. 21), in the introductory chapter of his Geography of Australia, states :—

"The high bank to the west of Bacchus Marsh, 1000 feet in height, up which the train climbs on the way from Melbourne to Ballarat, is one of the oldest, well-preserved valley walls in the world. It was carved out by river erosion in Silurian times. It was in existence beforê the materials of which most of the Alps are built had been laid down in the seas of central Europe. It was old before the first bird or mammal or reptile had been born upon the earth, and it dates back earlier than the building of the lands whose foundering formed the Atlantic Ocean. That old valley wall at Bacchus Marsh remained long hidden beneath sheets of sand, gravel and clay, the partial removal of which has once more rendered it an important feature in the Australian landscape. It has again been protected by a cascade of molten lava that poured over its edge from the volcanoes of the plateau behind it; and that coat of rock has given a renewed lease of existence to this venerable geographical feature."

Notwithstanding the literary merit of this account, the fact remains that the structure and materials of which this scarp is built at Bacchus Marsh quite preclude the possibility of its being older than Middle Tertiary. Ancient glacial valleys, to which the Professor's fine description may be applied, are elsewhere exposed in section in this district, as set out by Messrs. Brittlebank, Sweet and David (ref. 7).

T. S. Hart (ref. 24), in some notes in the Students' Magazine of the Ballarat School of Mines, of a few years ago, briefly refers to the scarp thus :—"The edge of the high ground here was probably determined by a fault scarp not altogether obliterated by newer

lava flows, and well marked in the boundary of the Ordovician rocks south of Rowsley."

The same writer (ref. 22, p. 26), believes that, at a point east of Trig Hill, Bacchus Marsh, "there is a monocline probably faulted, and further south along the edge of the high basaltic plateau, a fault scarp over which the lavas have flowed." He refers to its southern continuation, as indicated for about six miles on Quarter Sheet 12 S.E., and states: "As the line of fault passes between the old township of Rowsley and the railway station of the same name, I will call it the Rowsley fault."

In a map of the "Tectonic Features of Australia and Tasmania," accompanying Professor David's article on the Geology of the Commonwealth (ref. 12), there is a large E.W. fault shown, with a down-throw to the South; it is labelled "Bacchus Marsh Fault," and is evidently intended to indicate the northern boundary of the "Great Valley of Victoria." The Bacchus Marsh scarp, however, really runs almost north and south (see Fig. 5), and the series of E.W. faults that probably bound the "Great Valley" yet remain to be investigated.

Wilkinson and Daintree (ref. 56), in the sheet of notes attached to Quarter Sheet 12 N.E., refer to the scarp at Bacchus Marsh, and say:— "A similar feature must have existed in the Miocene formations prior to the flow of newer basalt, which has evidently flowed over a steep face 200 feet in height." The origin of the scarp is not discussed.

Professor Skeats (ref. 47, p. 208) also mentions this scarp, and says:—"It may be formed by denudation or may represent a fault scarp formed during the eruptive period."

Andrews (ref. 1, p. 477) refers to the "Bacchus Marsh Fault" as one of uplift, and adds: "Not yet examined carefully. It is a dismantled scarp to the north of Bacchus Marsh. Some of the associated basalts are older and some younger than the scarp."

The writer has carefully examined this scarp along nearly the whole thirty miles of its length, and has been greatly aided by the geological survey maps of the area, coupled with the contour maps of the Military Survey. He must confess to a regret that he was unable to examine the scarp with closer detail in the immediate neighbourhood of the Anakies, and in the few miles of more inaccessible country in the extreme north. He is confident, however, that such examination would only further confirm the results already arrived at.

Physiographic evidence.—The line of the scarp is almost straight, but, as shown on Fig. 5, is slightly concave to Port Phillip Bay. The general height of the scarp is considerable. The levels, indicated by 100 foot contours, as shown in Fig. 6, are copied, by permission, from the Ballan and Meredith Sheets of the Military Survey. These plans give the most exact interpretation possible of the line of the fault, based on geological and physiographic evidence,. confirmed in the field. Smaller contour intervals greatly emphasise the scarp.

One may approach the scarp in a direction normal to it at any part from the east, and travel twenty to thirty miles from sea level to reach an average elevation of 500 feet at the base of the scarp, a mean grade of 20 feet to the mile. Continuing in the same line, the next mile of progress would carry us up to over 1300 feet, a grade of 800 feet to the mile. Once on the plateau, we may proceed westward another twenty miles at a mean elevation of 1500 feet, an average rise of ten feet to the mile. (See Fig. 12).

The height of the scarp is greatest towards the northern part (about 900 feet), where it bounds the eastern face of the Lerderderg Ranges. It is best demonstrated along the fifteen miles running south from the Parwan area (average height here 800 feet), and is least pronounced at Bacchus Marsh (about 300 feet), and at the southern end, near the junction of the east and west branches of Sutherland's Creek (about 200 feet). Scaled sections across the scarp at various points are included in the portion of this paper that deals with the geological evidence.

The effect of the scarp has naturally been to give the established rivers on the higher block greater eroding powers. On the lower block the rivers all flow at even grades across the plains, while above the scarp deep precipitous gorges are the rule, especially in the hard Ordovician slates and sandstones. The Lerderderg gorge, at the point where that river crosses the fault, is nearly 1000 feet deep. The Werribee Gorge, one of the best-known scenic features in the area, is much more precipitous than that of the Lerderderg, and is up to 800 feet deep. Still further south, the "Anakie Gorge," on a tributary of the Little River, is about 700 feet deep where it crosses the fault. In all cases the rivers immediately pass, on leaving the gorges of the higher block, to shallow channels cut into alluvial material.

The multitude of minor streams which seam the scarp face, heading back at high grades into the higher block, closely approximate, in the nature of their valleys and spurs, to those outlined by

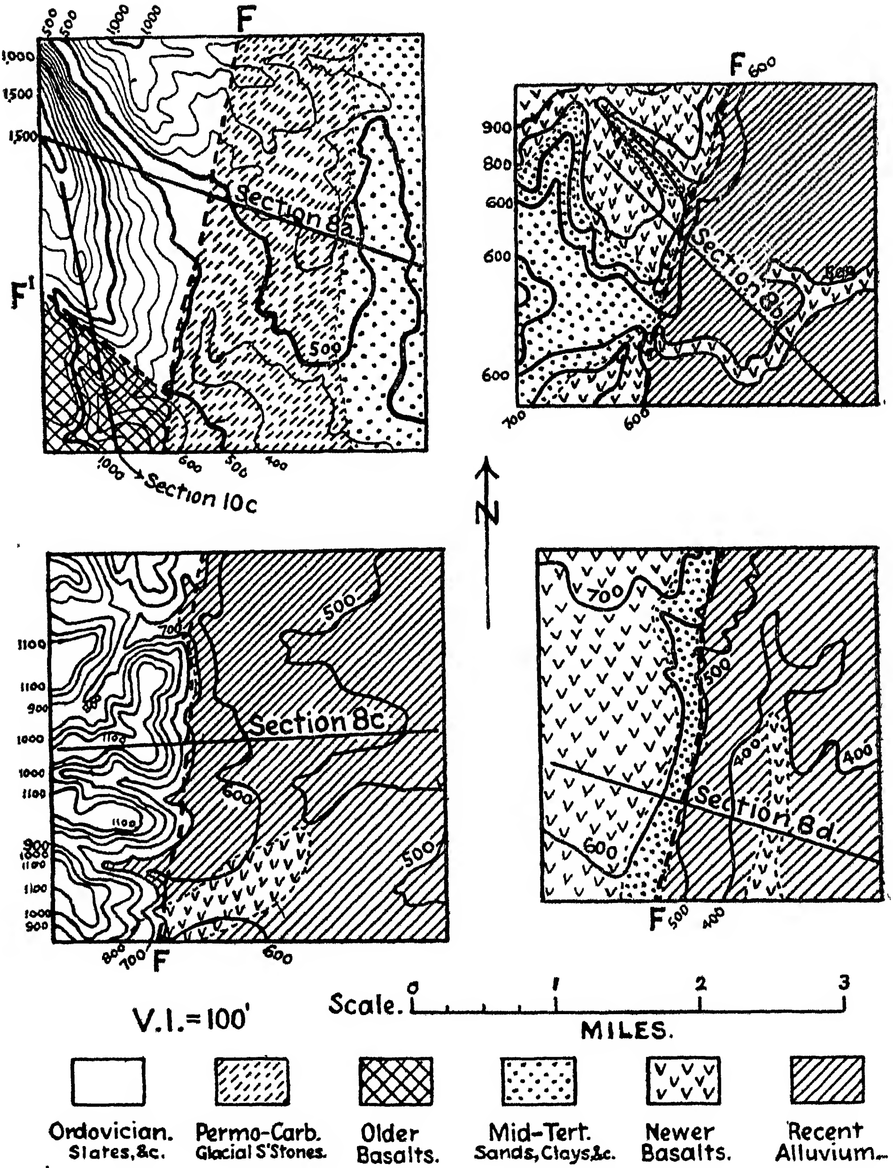


Fig. 6.—Plans of typical and critical portions of the Rowsley or Bacchus Marsh fault, showing 100-foot contours and general geology. The lines of the sections shown in Figure 7 are also indicated. F — Rowsley Fault; F1 — Greendale Fault. The localities are: a — near the mouth of the Lerderderg gorge; b — near Dog Trap Gully, Bacchus Marsh; c — north of the Anakies; d — south of the Anakies.

Professor Davis in his ideal diagrams of fault-block erosion (ref. 16). They are most definitely observable in the field, even if only noted from the plains when one travels along parallel with the scarp, as may be done along the foot of the Brisbane Ranges, or along the road from Bacchus Marsh to Bullengarook.

The physiographic facts alone thus provide strong presumptive evidence of the scarp being due to a fault. All along the base of the scarp, streams have deposited an apron of alluvium. This extends outward into the lower plains; it is usually over a mile in width, and in places reaches outwards for greater distances.

Geological evidence.—We may now examine the geological evidence for further proof, and especially for indications of the probable age of the fault with regard to the newer basalt.

The general geological relations may be seen from the plans in Fig. 6. We see that the higher blocks to the west of the scarp (A, B, and C, Fig. 2) are mainly of Ordovician rocks. On the lower side no Ordovician occurs close to the scarp base. In fact the only Ordovician whatever on the lower block E is that along the Pyrete and Djerriwarrh Creeks, and is exposed in valleys several hundred feet lower than the smiliar rocks to the west of the scarp. The boundary of the higher Ordovician is, moreover, quite sharp and almost straight, and cuts obliquely across the strike of those highly folded beds. The strike averages nearly due north, while the sharp junction with the various younger beds averages about 15° E. of North.

Four sections are shown in Fig. 7 (8a, 8b, 8c and 8d), drawn to scale normally across the scarp where the relations can be most clearly proved. It is natural of course that the lower margin should be in many places obscured by alluvium, as shown in the geological plan. The newer basalt sheet in places also partly obscures the fault. At least five important sections, however, may be examined where the true relationships with the newer basalt are shown. Such sections are especially interesting in so far as they have an important bearing on the age of the fault.

Section 8a shows the most northerly section that was critically examined, at a point where the Lerderderg River emerges from the ranges. It shows the glacial conglomerates let down and preserved to the east, along with middle tertiary beds, the latter being capped by the basalt of the Bullengarook flow. On the summit of the ranges here, small glacial remnants occur. These relations provide strong confirmatory evidence of a big fault.

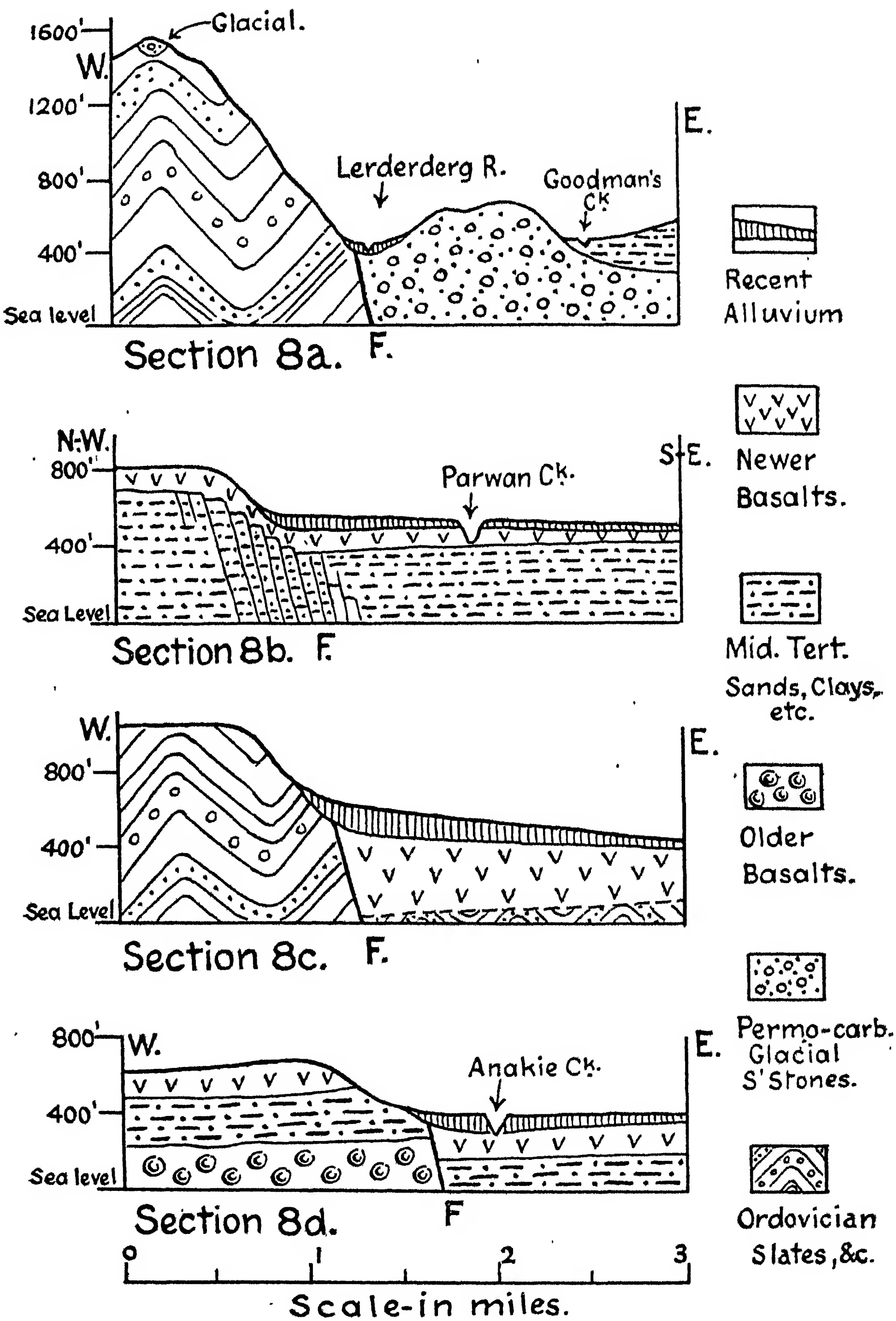


Fig. 7.—Sections across the Rowsley Scarp, along the lines shown in Fig. 6, showing geology and relief. F — Fault.

Where the Werribee river cuts the scarp, soft tertiary materials abound, and the wide, soil-covered valley slopes do not provide any good sections. A point east of Trig Hill, however, attracted the attention of the survey in 1868 (ref. 56), and has also been examined and commented on by Mr. Hart. The usually level tertiary beds here show an easterly dip, possibly due to "drag" along the fault line. Mr. Hart expresses somewhat the same idea by calling it a "faulted monocline." (ref. 22, p. 268).

A little further south there are three important sections:—(i.) on the right bank of the Dog-Trap Gully, above the railway line, (ii.) on the right bank of the Parwan, where it crosses the scarp (referred to in 1868; note 16, Quarter Sheet, 12 N.E.), and (iii.) in the cutting where the road passes over the eastern ridge into the Parwan Valley, a short distance to the south of the last point. The sum of the observations at these three points was that the basalt capping the higher block along the edge is now very thin, that the tertiaries remain on the whole level-bedded close to the edge of the scarp, and that the junction between the two thence descends steeply eastward. These relations are diagrammatically shown in Section 8b. The "Parwan Creek" shown in this section indicates the small valley cut into the alluvial and basalt by the lower Parwan, east of the scarp.

The Dog-Trap Gully is of further interest, inasmuch as it exposes along its left bank the side of a thick body of basalt that apparently fills an old valley which once existed there.

Section 8c shows the typical relations of the scarp face further south along the eastern wall of the Brisbane Ranges. The relations immediately at the foot of the scarp are somewhat hidden by alluvium, but stream sections show the volcanic sheet, in places, continuing up to the scarp. We cannot be sure that it does continue everywhere sharply up to the edge of the Ordovician, but a shaft sunk by the Geological Survey (Quarter Sheet 12 S.E.), in the alluvium about one and a-half miles east of the scarp, bottomed on basalt at 42 feet. If the basalt of the lower plains, at this point, ever existed on the top of the higher Ordovician block, we might expect to find evidence of this fact in the alluvium lying on the volcanic sheet near the base. In this connection it is of interest to note that Wilkinson's survey party, in 1863, in the shaft just referred to, found and recorded basalt boulders at depths of 13 ft. 6in., 26 ft. 6 in., and 28 ft. 9 in. It is of course possible that these boulders were derived from the denudation of the low basaltic hills to the east of the scarp, and carried thence by stream action.

Similar boulders, if found to occur generally over this alluvial area, at such varying depths, would point to the one-time existence of basalts on the high land to the west of the scarp, where Ordovician is now exposed.

Further south at Anakie Gorge, right bank, decomposed igneous material banks close up against the Ordovician face, with a high angle junction; the volcanic material undoubtedly continues right up to the base of the scarp at this point. (Fig. 7, Sect. 8c.)

Section d is a section through the scarp at about the locality of O'Neill Bros.' farm, some five miles south from Mt. Anakie, and east of the village of Maude. The higher basalt shows an even, level, lower margin right to the edge of the scarp, and reappears on the plains below, where exposed by the Anakie Creek (east branch of Sutherland's Creek). The Anakie creek here flows parallel to the fault, a little to the east, and receives its main tributaries from the high scarp bank to the west.

There is no need to further enlarge on the proofs of faulting as shown by the sections. The evidence is quite sufficient to fully justify us in finally accepting this scarp as due to an extensive fault. We shall retain Mr. Hart's name of the "Rowsley Fault," although it may appeal more widely to geologists as the Bacchus Marsh Fault.

The age of the fault, on geological evidence, is undoubtedly post-Ordovician, post-permo-carboniferous, post-older-basaltic, and post-middle tertiary, since it has intersected and thrown down all these formations at various points. Both Wilkinson (ref. 56), Hart (ref. 22), Gregory (ref. 21), and Andrews (ref. 1), believed the feature to be pre-newer basaltic. If so it is scarcely credible that the level-bedded and very easily eroded tertiary sands as shown at Dog-Trap Gully, etc., could have preserved, for even a brief period of time, the steep face shown in section (Fig. 7b). Moreover, the sharp junction with volcanic rock at the base of the scarp at Anakie Gorge (Fig. 7c), and the section as shown at O'Neill's (Fig. 7d), at the southern end of the fault, when considered in conjunction with the sections as Dog-Trap Gully (Fig. 7b), provide fairly conclusive proof of its origin having been post newer basaltic.

The basalt-filled valleys above the scarp, now exposed in river sections, are comparatively shallow, suggesting that the area had not been uplifted prior to the basalt flows.

There is, however, another possibility of which mention should be made. In the absence of decisive proof (in the immediate neighbourhood of Bacchus Marsh) of the pre-newer basaltic origin

of the scarp, we must admit the possibility of the fault having occurred during the newer basalt period. The lavas along the southern part of the scarp, east of Maude, etc., must have been poured out, prior to the faulting, while those near Bacchus Marsh may have, in part, been poured out during its formation. Professor Skeats, as already quoted (ref. 47, p. 208), suggests that the scarp may have been formed "during the eruptive period," while Mahony (ref. 39, p. 377), refers to the possibility that "the newer basalts mark the close of the last great movement which elevated the marine Kainozoics."

The scarp at Bachus Marsh was viewed by Professor W. M. Davis, during 1914, and discussed by him with Dr. Summers. The latter gentleman informs me that the Professor's suggestion was that, if a fault, it was post newer basaltic, since a basalt flow could not, from its mobile nature, have clothed the scarp as it appears to-day. This expression of opinion, from so great an authority, must be accounted as valuable evidence against a pre-newer basaltic age, especially when the available evidence of the sections examined so strongly favours the belief that the newer basalt sheet was present when the fault occurred.

It must be admitted that the appearance of the slope, where the rocks are exposed on the right bank of the Parwan (Note 16, Quarter Sheet 12 N.E.), (see Fig. 32), gives an impression that the basalt "flowed" over the slope. It may be that in these tertiary clays and sands, with their strong covering "roof" of basalt, we did not get a sharp line of fracture in all places, but rather a zone of fracture, in places of a monoclinal nature, to the slopes of which the basalt sheet accommodated itself by movements along its very abundant joints and cracks. (Fig. 7b.) However, the sum of the evidence, as already shown, favours a post-newer basaltic origin.

Notwithstanding our lack of knowledge concerning the rate of erosion in the various rocks, it is permissible to say that the physiographic evidence also points to a comparatively late age for the scarp.

Other hypotheses have been put forward regarding the origin of this scarp—that it was an old sea cliff (ref. 6), a river cliff, etc. These ideas were kept in view when examining the scarp, and there has been found not the slightest evidence in favour of any other explanation than that of faulting. To briefly recapitulate the facts as seen in the field, we may once more take a rapid survey of the whole line.

Beginning near the southern end, north of the River Moorabool, we find the fault represented by a "bank" or scarp, from 200 to 300 feet high on the western side, geologically distinct from the lower plains to the east. Where the line crosses Sutherland's Creek and the Moorabool River, two very distinct formations (the older basalt and the "thin, persistent limestone band") are abruptly cut off, and appear only on the up-throw side of the fault (see Geological Quarter Sheet 19 S.W.). To the south of these points the scarp has not been traced, and apparently disappears. Continuing northwards we find the scarp capped by newer basalt, which reappears 250 feet lower on the down-throw side, partly covered by an apron of alluvium. The cutting off of this volcanic sheet appears to have been quite abrupt.

Further north we have the high peneplain (1300 feet average) of folded Ordovician slates to the west, abruptly descending to a volcanic plain (500 feet average), with a characteristic alluvial apron along the base of the scarp. The cutting off of the Ordovician is along an almost straight line, which runs obliquely across the strike; the general height of the scarp face here is 800 feet. At the Anakies we find that a resistant granite mass in the let-down block, near the scarp, and a piling up of volcanic material below and on the fault line, has somewhat obliterated the straightness of the junction, and has made it possible to carry a road from the lower plains to the top of the ranges on the west.

Beyond the Anakies, at Anakie Gorge, the low basalt (5-600 feet) comes abruptly to the edge of the Ordovician slates, which then rise at once to a general level of 1350 feet. From this point on to "Greystones" (near the top of Quarter Sheet 12 S.E.), the physiographic evidence is excellent; deep gorges score the face of the high resistant scarp, and the streams continue on the lower block, in wandering shallow channels across the alluvial apron, to the basalt plains.

Further north, the nature of the country alters completely, the fault line turns north-easterly, and then again more northerly through Bacchus Marsh. Newer volcanics mask the scarp, except where exposed in sections. The Parwan and Werribee have cut deep into the uplifted block and show the geological structure west of the fault to be of the complex nature common to the "Ballan sunkland" (block C). The scarp here is generally lower; basalt in most cases covers the slope, and occurs both upon the upper and lower blocks. It is suggested (Fig. 7b) that the basalt sheet must have undergone fracture slowly, and have thus clung

along the slope, and so remained. This is the portion of the scarp most difficult to read.

Where the glacial sandstones of the southern part of Bald Hill remain on the up-throw side of the fault (see Fig. 10), they show excellent exposures in plan and section of these beds, with a steep dip easterly towards the down-throw side of the Rowsley Fault. This fact, considered in conjunction with the already mentioned tilting of the tertiary series (ordinarily level-bedded), suggests that where the Rowsley Fault intersected the younger, more varied, less compacted, and more level-bedded rocks of the "Ballan sunkland," it partook more of the nature of a monocline. This is in sharp contrast to the abrupt break that marks the fault where it cuts through the harder folded Ordovician slates and sandstones.

North of Bacchus Marsh, the great valleys of the Lerderderg and the Korkuperrimul, with their thick alluvial terraces, obliterate the actual fault, which runs about a mile up the Korkuperrimul and then passes to the eastward of Bald Hill, continuing as the eastern boundary of the Lerderderg ranges. Near the point where the Lerderderg emerges from the Ranges, a fault coming from the north-west cuts across the scarp, and to the north of that we once more get a great resistant block of high Ordovician (Lerderderg Ranges) to the west, with less elevated Ordovician, glacials and tertiaries to the east. Thence the country is very difficult of access, and while the fault probably continues and dies out in the neighbourhood of Bullengarook, the evidence for this is wholly physiographic, and was not closely investigated.

We may conclude then that the Rowsley or Bacchus Marsh scarp is due to a fault, is most probably post-newer basaltic in age, is certainly so in part, has an average displacement of about 800 feet, and is at least thirty miles in length, trending about 15 to 20 degrees E. of north, and bounding the eastern faces of the Brisbane Ranges, the "Ballan Plateau," and the Lerderderg and Blackwood Ranges (see Fig. 5). Since the movement was probably one of uplift of the higher blocks (A, B and C), rather than a let-down of the lower block (E), it may be that it was contemporaneous with those uplifts that are classified as occurring in the "Kosciusko Epoch."

(ii.) *The Greendale Fault.*—The second important physiographic feature of the area is what we may refer to as the Greendale Scarp, forming the boundary between the blocks A and B (Fig. 2), and being the southern boundary of the great dissected block of Ordovician (Blackwood and Lerderderg Ranges), which stretches from

the village of Greendale northward beyond the Main Divide of Victoria.

The existence of this fault was, the writer learns, suspected by Messrs. Hart and Baragwanath, but no references to it occur in the geological records of this State. In January, 1915, the University Geological Survey Party, under Professor Skeats, gave critical attention to the scarp, and clearly demonstrated its existence as a fault for some six miles, in the parish of Blackwood. The writer has since extended these observations to the west and the east, and has been permitted by Professor Skeats, and by Mr. Herman, Director of Geological Survey, to embody in this paper the evidence collected by the Survey Party referred to.

The whole of this area is known to be traversed by faults, running at all varieties of angles both across and with the strike. By far the most definite are the E.-W. series, as proved in the underground workings at Blackwood. W. H. Ferguson (ref. 18, pp. 5 and 26) records twelve "cross courses" (E.-W. faults), within a distance of three miles, in the Blackwood field. They are all vertical or moderately inclined, and in some instances the fissures are filled by dyke material, one being over 100 feet wide. The movement does not seem to have been very marked in most cases, and in many fractures there was no movement at all.

It would seem futile to endeavour to approximate an age for such faults and fractures as a whole, seeing that these lower Ordovician rocks have been the sufferers of every thrust and screw and crush to which this part of the lithosphere has been subjected since those lower palaeozoic times. There can be no doubt that the fractures and faults had their origin at many and various times, and that along any one ancient fracture line, movements may have occurred at every period of diastrophism since then.

There is a peculiar and interesting generalization which has been put forward concerning several areas of Victoria, viz. :—

(1) N.-S. dykes are acid.

(2) E.-W. dykes are basic.

Accepting as part of our creed that the devonian was par excellence the period of activity of acid magmas, and the tertiary as the chief period of the uprising of basic material, there would seem to be appreciable a further generalization to the effect that the E.-W. fractures were largely post-devonian, and the N.-S. fractures largely pre-carboniferous in origin. Many other factors and many other areas will need to be investigated before any generalization of value can be arrived at, but in a section dealing with the age of faults the idea was thought worthy of mention.

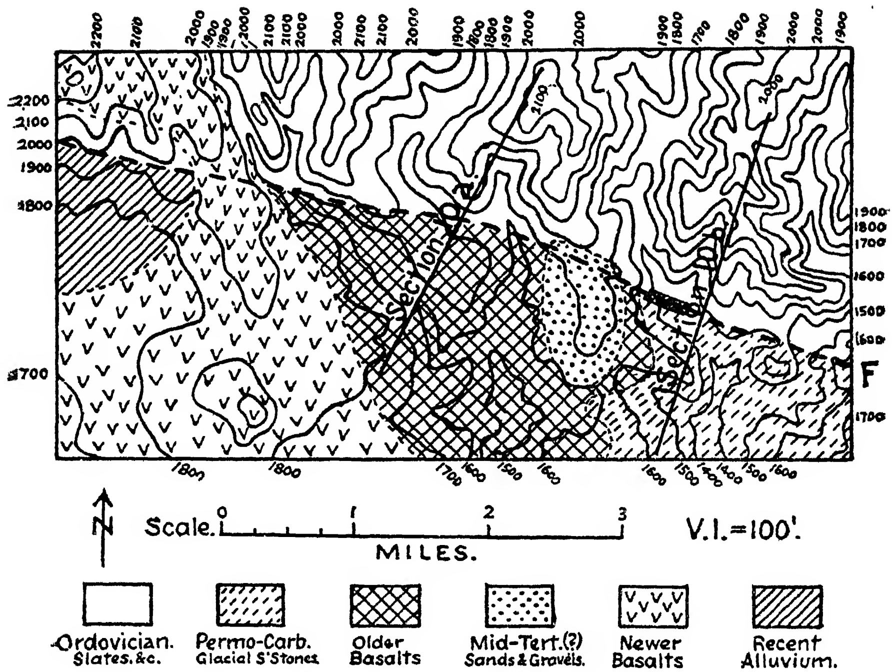


Fig. 8.—Plan of portion of the Greendale scarp, extending from Larkin's or Bald Hill in the west to beyond Greendale, showing 100-foot contours and general geology. The lines of the sections shown in Figure 9 are indicated. F — Fault.

The total length of the Greendale scarp is about eighteen miles. Fig. 8, with 100 feet contours taken from the maps of the Military Survey, shows also the geology of a large portion of this scarp. The evidence both physiographic and geological, is closely parallel to that of the Rowsley Fault. There is a varied area of hill, valley, and plain on the lower block B (referred to also as the Ballan sunkland), of an average elevation of 1500 feet. North of the scarp the average elevation is over 2000 feet; the transition from the lower to the higher level is usually abrupt, as shown in the sections which will be referred to. The scarp runs generally a few degrees south of east, turning to south-east beyond Mt. Blackwood. The line of the scarp is not straight, but this is quite in accord with the general characteristics of faults. As stated by Professor W. M. Davis (ref. 16):—"The fault may be nearly a plane or a conspicuously curved surface, but from all that is known of faults, it cannot possess sharp or exaggerated irregularities such as are seen in the septa of an ammonite."

Geologically, the evidence of the scarp being due to a fault may be best indicated by reference to three critical sections. Since these are drawn to scale, as in the case of those illustrating the Rowsley Fault, they also present important physiographic corroboration.

Immediately north of Greendale, where Dale's Creek emerges from its gorge in the higher Ordovician block, there is an excellent geological section indicated in the creek bed. This is shown

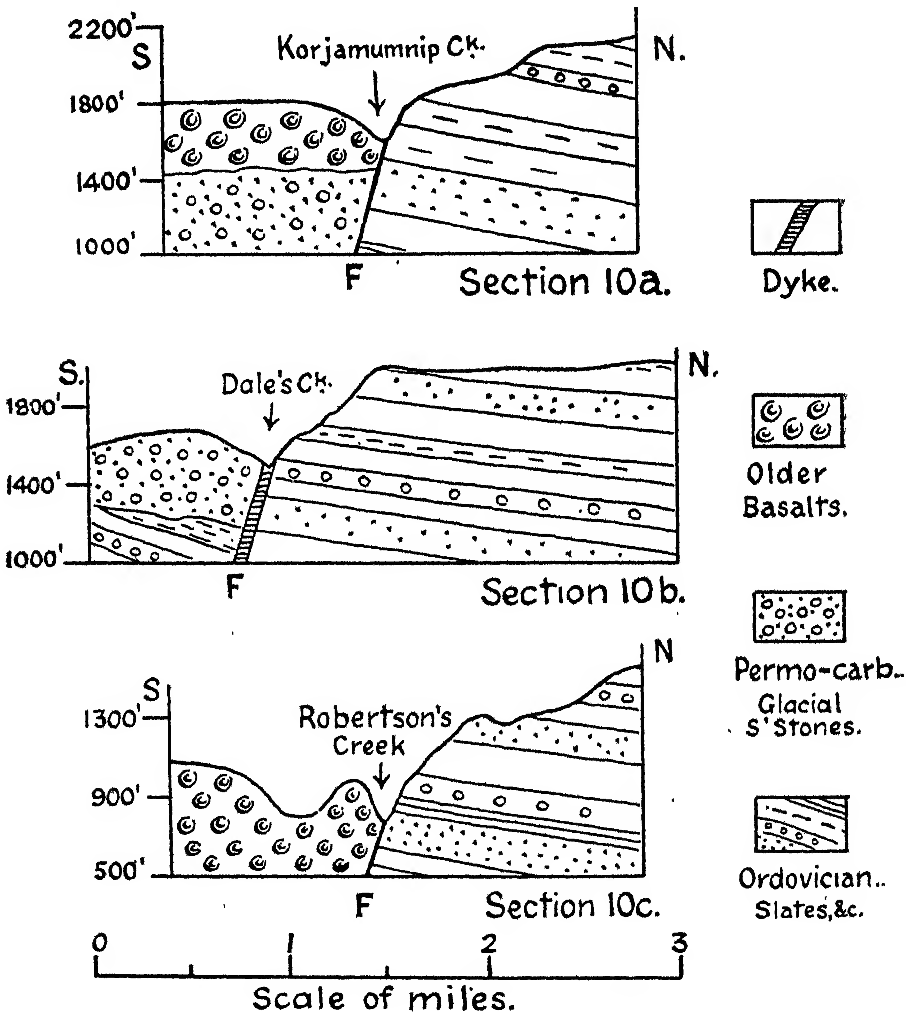


Fig. 9. Sections across the Greendale Scarp, along the lines shown in Fig. 8 (a and b), and Fig. 6 (c), showing geology and relief. A dyke marks the fault line in Section b.

by Fig. 9 (b). To the north rise the high Ordovician ranges, and in the creek-bed the upturned edges of these hard Ordovician slates are cut off sharply by a large east-west dyke. Immediately south of this dyke, the glacial (permo-carboniferous) sandstones occur. In a quarry a few hundred yards further south the same series is seen to be tilted to the north-west, and thus they must be butting directly against the Ordovician, a fact only capable of explanation by assuming a fault of a fairly extensive throw, probably 1000 feet. To the east of this point, small residual ridges, butting against the base of the Ordovician scarp, were dug into, and proved likewise to be Permo-carboniferous.

Further west, where the Korjamumnip Creek turns east for a short distance along the base of the scarp, we get the section shown in Fig. 9 (a). Here older basalt, undoubtedly resting on glacial sandstones, has been let down against the Ordovician. A visit to this point in the field provides excellent "fault evidence," both geological and physiographical. One stands on a low area of decomposed older basalt, cut off sharply along its northern boundary by Ordovician rocks; the latter are cut clean across the strike, and now rise above the observer in steep triangular-faced spurs, rock-strewn, and clothed with timber and bracken. Thick deposits of "scarp-base alluvials" lie on the older basalt a little to the east, and on the west the effect of the fault is further seen in the deflection of the creeks.

Further west, a tongue of newer volcanic passes, undisturbed, across the fault line; a series of bores put through this flow close to the line of the scarp gave the following results (ref. 40):—The newer volcanic, was proved by the first two bores recorded to be somewhat less than 200 feet deep, and of course underlain by river gravels. No. 3 bore, however, passed through 757 feet of basaltic rock without reaching bottom; either the older volcanics are developed to a great thickness close against the scarp, or else the bore came upon the wide dyke (referred to above) which is known to mark the boundary of the scarp for some distance; in either case the bore provides good confirmatory evidence in favour of a fault.

Further still to the west, the scarp may be clearly seen, but the development of newer-basalt flows on an extensive scale somewhat complicates matters. While it is quite possible that permo-carboniferous occurs on the flat ground south of Frichot's house, this has not been proved. The general higher Ordovician, however, continues on past the south of Bald or Larkin's Hill, and then on to the northward of Egan's Hill. It is very significant that no ter-

tiaries or glacial deposits occur north of the scarp line in this part of the State, but such are found quite common (many of them unmapped) to the south of that line. The down-throw of the fault in its western part has probably been much less than at Greendale. Here, too, the fault passes away into the upper Moorabool area, and as the writer found it necessary to restrict detailed work to the prescribed area, further work to the west of Egan's Hill was not done.

In many places remarkably coarse conglomerates and gravels, 40-60 feet in depth, are piled up close against the scarp, notably so at Garibaldi Hill and Shuter's Hill, Greendale. They are much more dissected than the alluvial apron which lies along the base of the Rowsley scarp, and point to the greater age of the Greendale scarp. They are no doubt relics of the early deposits along the steep scarp face. The two deposits specially referred to suggest "fan deltas" in their shape, and in the extreme coarseness of the boulders close to the scarp.

Eastward from Shuter's Hill, the lower side of the scarp is of Ordovician slates similar to those of the higher block, but there is still a marked difference between the physiography above and below the "fault line." Blocks of fault conglomerate are strewn on the slopes here, and the wide valleys below the fault grade into the steeper-sided ones to the north. They remain, however, sufficiently distinct to enable the line to be followed.

Coming to Mt. Blackwood, we find that dominant hill to be a cinder cone perched on the uplifted block., near the edge; the contour of the flow proves that the valley down which it ran had a much steeper grade near the base of the hill, so that practically the whole of the lava flow ran down and debouched over the plain, that which remained above being mainly scoria. The exact line of the fault is here less clearly defined, but it is assumed that the remarkably steep descent of about 400 feet, shown in the present contour of the lava flow (Fig. 21), marks the point where the fault line crosses this area. Beyond this, we find the fault more clearly defined, stratigraphically, and trending south-east. It follows and then crosses the Korkuperrimul Creek, and we have once more glacial, older volcanic, and tertiaries at a much lower level than the Ordovician; where noted in the field the junction was abrupt and almost straight. David (ref. 13) refers to great differences (nearly 800 feet) in the levels of the known glacial pavements here. It is accepted that the glaciers moved northwards, about 12° E., and yet the Professor mentions that the base of the

glacials lies at 660 feet in the Werribee Gorge, and at 1400 feet in the Lerderderg area (about 5-6 miles N.-N.E.). This anomaly is explained by the intervening fault.

The fault after crossing the Korkuperrimul, forms the northern boundary of the big let-down glacial block east of that river. For a few miles here, the writer is assuming the fault on the basis of previous geological and contour surveys, where the evidence is analogous to that of areas where the line was closely examined. Observations from viewpoints to the east and west confirm the assumption that the fault thence continues past Mr. Robertson's house, "Highlands." Here Robertson's Creek has followed the fault for some distance, providing excellent and unmistakable exposures. As we pass down this creek, we find always on the left the high block of Ordovician which forms the south-eastern triangular termination of the Lerderderg Ranges. (Fig. 6a.) To the south-west we invariably get younger beds, let down, and tilted at varying angles towards the south and south-east; these consist of the Bacchus Marsh tertiaries, thick flows of older volcanic, glacial sandstones and conglomerates, and also what appeared to be sub-glacial river gravels; all these deposits show signs of disturbance. The Greendale scarp then meets the Rowsley or Bacchus Marsh scarp. The consequence of this is of course that the northern continuation of the Rowsley fault has a much greater throw than further to the south.

Physiographically, in addition to the abrupt change of elevation mentioned and shown in diagrams, we have various features in the rivers which point to the truth of the explanation of the Greendale scarp as being due to a moderately rapid uplift of the northern block; it was considered more convenient to deal with such features when describing the rivers. As already detailed, conclusive fault evidence occurs abundantly in the field, much more telling than diagrams and descriptions. Still, the evidence so far put forward in this paper is sufficient to show positively that the scarp described marks a line of extensive faulting. In consideration of the fact that it was first definitely proved near the village of Greendale, it is called the "Greendale fault." For plan see b, Fig. 5.

To come now to the question of age, we find that, while in some cases the face of the scarp is remarkably well preserved, there is other physiographic evidence (such as the greatly dissected nature of the alluvial apron) which suggests that this scarp is much older than that of the Rowsley Fault.

There are points along the face of the Greendale scarp where the evidence would seem to favour a more recent age than that assigned in this paper, as far as the recession of the scarp face by erosion is concerned. Likewise there are places along the Bacchus Marsh scarp where erosion is so far advanced as to suggest a greater age than is here given. Many other similar anomalies were noted, pointing to the impossibility of making correct calculations as to relative age purely on the physiographic appearance of limited areas.

That the Greendale fault was post permo-carboniferous and post older-basaltic is clear from the geological plan (Fig. 8), and sections (Fig. 9 a, b and c), There cannot be any doubt that subsequent to the fault some glacial and older basalt remained on the higher block, and have since been almost entirely destroyed. Scattered striated pebbles were found on the crests of the ranges, as were small patches of glacial conglomerate previously referred to. The writer also came across an area of scattered basaltic boulders marking the truncated neck of what was probably an older volcano; this was high up on the Ordovician peneplain to the north of Greendale and has been mapped.

The road that passed Mt. Steiglitz proceeds on to the north towards Blakeville along a tongue of basalt. This is undoubtedly newer volcanic, though coloured as older basalt in some geological maps. The depth and maturity of the valley so filled by basalt is abundant proof that the fault is much older than the newer volcanic flow which fills it. It may possibly be correlated in age with the first great period of uplift of New South Wales geologists (ref. 48), but is here plainly subsequent to the older basaltic lavas.

(iii.) *Minor Faults.*—Several other faults occur in the Werribee River area, but these were not so minutely examined as the two main ones already described. They will be dealt with as under :—

More extensive faults:
- a. Fault bounding the southern edge of Block D.
- b. Fault bounding the southern edge of the Ballan sunkland.
- c The Steiglitz Fault.

Less extensive faults:
- d. The Coimadai fault.
- e. The Bald Hill faults.
- f. Other small faults.

(a) Fault bounding the southern edge of block D (see e, Fig. 5). The evidence in this case is largely physiographic, since, as will be seen from the geological map, the higher Ordovician block is more dissected and largely covered by newer volcanic cones and flows,

grading down to the lower basalt-covered Werribee plains (block E). Towards the west there are two large areas of glacial conglomerate on the down-throw side, but otherwise there are no geological distinctions between the two sides of the suggested fault, due largely to the extensive erosion and the covering of volcanic material.

Physiographically, we find this Gisborne block, whose elevation is much increased by such volcanic masses as Mts. Bullengarook and Gisborne, is really on the average much lower than Block A—the Blackwood and Lerderderg Ranges, and slopes downwards to the east. The wide east-flowing valley of the Gisborne Creek occupies the main part of the block, and this valley extends across to the Main Divide at Macedon. There is, however, a fairly sudden drop along a general east-west line, as may be noted when travelling up the Bullengarook road, at the point where the basalt flow is very narrow (see Fig. 22). The road from Coimadai to Toolern Vale runs along parallel to and somewhat south of the line believed by the writer to mark this fault. To the north are higher, severely-eroded, timbered ranges of folded lower Ordovician slates, quartzites, etc., but the lower area traversed by the road shows abundant gravelly deposits, some basalts, and a little permo-carboniferous, while the Ordovician here outcrops mainly in the creek beds.

On the main road from Gisborne to Melton we again find an extremely steep fall of over 400 feet in little more than a mile (Breakneck Hill). Further east, outside the area examined by the writer, there is a steep climb for the train after it leaves Sunbury for the north; this rise is mainly due to the erosive work done by Jackson's Creek.

The western part of the block, at the head of Pyrete and Djerriwarrh Creeks, is a very deeply dissected mass of folded Ordovician slates, etc. The exposures of these rocks become less extensive and less rugged as we go east, and volcanic rocks become more and more in evidence. To the south on the let-down block no Ordovician occurs, except at a very low level (about 600 feet) in the valleys of the Pyrete and Djerriwarrh creeks, as may be seen where the Melbourne road crosses those streams, or higher up near Coimadai. Between the lower and the higher Ordovician a fall of over 400 feet is distinctly noticeable. This difference of level rapidly decreases to the eastward.

The most convincing physiographic evidence is found in the grades of the rivers. The Pyrete, Djwerriwarrh and Toolern creeks flow south from the Gisborne highlands into the Werribee.

The grades of the Djerriwarrh, Toolern, Boggy and Condon's creeks have been carefully plotted in Plate XIIIB. An inspection will show that they clearly tell a story of rivers rejuvenated in their upper reaches. The lower five miles or so of these streams show a gentle rise of 100 feet to the mile. At the point where other physiographic evidence suggests a fairly well-dissected scarp line, these streams rise 500 feet in a mile—a grade five times as steep as that below; thence to the top of the highlands the grade is less steep, giving us a line of the nature shown in Fig. 25. This is a quite similar line to that of the Lerderderg and Werribee, due to their rejuvenation by faulting (see also Plate XIIa.), as well as to that given by Chamberlin and Salisbury (ref. 10, p. 163) in their diagram to represent the grades of a partly rejuvenated stream.

The evidence presented, though not as complete as could be wished, owing to the reasons stated, is yet sufficient to enable us to map approximately the "Gisborne Fault,"—which here forms part of the northern boundary of the great Port Phillip sunkland. The fault has its greatest throw in the west, where the deeply-ravined Ordovician of the upper Pyrete creek, etc., occurs; the throw becomes much less as we proceed eastward. No date can be definitely stated, but the writer believes it to be probably of the same age as the Greendale fault.

(b) *Fault bounding Southern edge of the Ballan Sunkland.*

(See Fig. 5.) The very important sunkland of Port Phillip, and the less extensive but equally interesting one of Ballan, which will be dealt with in detail later, have already been referred to. These names are introduced at this point since it is felt to be the most convenient method of referring to those particular areas. In dealing with the southern edge of the Ballan sunkland, the writer is again describing a feature which extends for some distance out of his limited area. It has only been examined where it lies within the Werribee basin, and other evidence to the west is based on published geological maps and records.

Physiographically we have no evidence of this fault, except that the valleys immediately north of the fault, being in the much younger and softer beds of the let-down rocks, are much wider than those to the south. There is now no scarp present, as is indicated in the north south section (Fig. 13); this figure also shows, diagrammatically, the geology of the section. Spring Creek, a tributary of the Parwan, flows for part of its course along the boundary between the Ordovician and tertiary, i.e., along the fault

line. Where investigated by the writer, this valley is steep and V-shaped, over 300 feet deep; on the right bank the high resistant slates, etc., of the Brisbane Ranges occur, truncated at right angles to their strike, while in the bed of the creek and high on the left bank, easily eroded tertiary beds ("leaf-beds") occur. These are capped by newer volcanic, which further west extends well over the fault line towards the south. Two streams—a southern tributary of Yaloak creek (flowing north), and the eastern Moorabool (flowing south)—cross the fault line, and might be expected to provide good sections. This is found to be the case, since the geological map of the parishes of Bungeeltap, etc., by Mr. E. J. Dunn (recently published) shows valuable confirmatory geological evidence of the fault.

In the Eastern Moorabool the steep valley sides change abruptly from the hard Ordovician to the soft tertiary sand and clay beds. The Yaloak creek tributary shows just as sudden a cutting off of these two formations, giving rise to the peculiar tributary, like an inverted T, shown in Fig. 37. Both junctions referred to are in an almost straight east-west line, and are also in line with the area on Spring creek, where the fault was first assumed by the writer. Mr. Dunn's map was kindly brought under my notice by Mr. Baragwanath. The writer has mentioned this evidence to Mr. T. S. Hart, and he suggests the same fault may continue to the west and form the southern wall of the very deep basin of the Lal Lal brown coal beds (ref. 24). The pre-existence of this fault junction may have influenced the Rowsley fault, causing it to change direction slightly at the point of intersection.

This fault, which may be called the Spring Creek Fault, is therefore put forward as the explanation of the very significant structural line separating the barren and unproductive Brisbane Ranges from the rich and geologically varied area of the Ballan sunkland to the north. It is perhaps of the same age as the Greendale fault, runs nearly east-west, and has a considerable down-throw to the north.

(c.) *The Steiglitz Fault.*—Mention of the Steiglitz fault is included here, in order to have as complete a record as possible of the chief faults within this area. The writer has, unfortunately, been unable to follow this line; he has, however, examined the country to the northward, at Steiglitz, both geologically and physiographically, as he has also done to the south, in the Maude and Lethbridge areas.

The contrast between the two parts visited, when compared with other similar areas which have been closely examined, strongly suggested an important break between the two, with a let-down to the south. This evidence also fitted in with the fact that from nearly every distant view, a peculiar break was noted in the level summit line of the Brisbane Ranges. All of this was of course insufficient evidence on which to assume a fault. The writer has, however, been delighted to discover that an extensive fault has been proved to run through south of Steiglitz; it has been located and investigated by Mr. W. H. Ferguson, of the Victorian Geological Survey, and the evidence is of a most striking and complete stratigraphical nature. Mr. Ferguson's report is, unfortunately, so far unpublished, but permission to include the foregoing statement in this paper has been kindly granted by the Mines Department.

(d) *Coimadai Fault.*—(See d Fig. 5.) This fault is probably of the same age as that at Greendale. The fault line is short, about five or six miles, and runs east-west with a down-throw to the south. The evidence is both physiographic and geological. The ancient "Bullengarook creek," now filled by the Bullengarook lava stream (ref. 42), flowed across this fault.

The country to the north is much higher than to the south. On the western side of the Bullengarook lava flow, Back creek flows eastward along the fault. On the left bank (north) the Ordovician rises steeply, and on the right bank there is a large area of glacial conglomerate. The boundary line, as mapped by Officer and Hogg (ref. 43) is almost straight, but it does not appear to be referred to by these writers as a fault. They apparently regarded the east-west Ordovician escarpment as a pre-permo-carboniferous feature—surely a physiographic impossibility, since the great mass of permo-carboniferous glacial rocks, that now lie at a much lower level near the base of the scarp, are accepted as relics of glaciers that flowed in a northerly direction. Hart (ref. 22, p. 257) records his belief that this line would be found to mark a fault.

On the east of the Bullengarook basalt tongue, the limestones, tertiary sands, and glacial beds of Coimadai are on the let-down side of the fault, while the steep "pinch" on the road that runs north from Coimadai to "The Basin" is really ascending this fault scarp. It is quite likely that differential erosion has accentuated the scarp just here, but the geological relations are conclusive.

(e) *The Bald Hill Faults.*—These faults are best seen in the field in summer, when the grass is dry, and the soil differences are most apparent. They occur at Bald Hill, north-west of Bacchus Marsh,

and form the boundary between the older basalt (black clayey soil) and the glacial sandstones (light sandy soil).

It was thought advisable to closely investigate the faulting of this area, as typical of the small faults that are believed to abound throughout the whole of the Ballan Sunkland. Both the geology and physiography proved to be of much interest. Fig. 10 shows the particular area in some detail, with 50 foot contours. Bald Hill itself forms the central portion of this plan, running from the north to the south. The steep bounding valley on the western side is that of the Korkuperrimul Creek, while the wider valley, partly shown on the east, is that of the Lerderderg River. At least four faults occur in this small area, and their influence is very clear both in the geology and the topography. These faults are marked by the letters A, B, C, and D. The fault marked A has been already described as part of the Greendale Fault; B is portion of the Rowsley Fault; C and D are two smaller faults that we may call the "Ball Hill Faults."

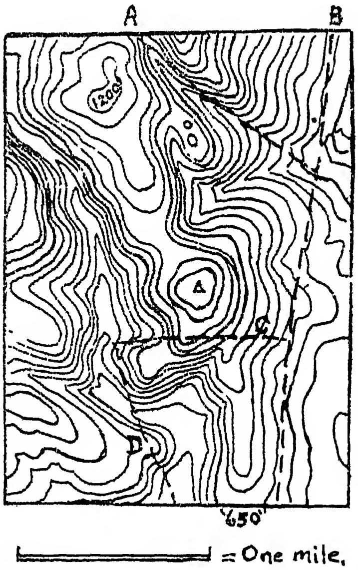


Fig. 10.—Contour plan of Bald Hill, near Bacchus Marsh. Fifty feet vertical intervals. A, B, C, D indicate faults referred to in Section VIIIb.

Geologically, there faults form almost exact boundaries. For instance, the triangular patch in the north, bounded by faults A and B, is Ordovician—portion of the high Lerderderg Ranges.

The low country, with gentler slopes east of Fault B, is of tertiary and terrace material, with a little low-level glacial in the northern part. The southern and lower part of Bald Hill, enclosed by faults D, C, and part of B, is a block of permo-carboniferous glacial sandstones, with a distinct easterly dip. The remaining area in the plan, the western portion, consists of high steep hills of older basalts, dipping down under tertiary leaf beds to the south. Not only have we this distinct geological evidence, but three of the four faults in this small area have been selected as stream valleys. The field evidence for fault C is good; although no section is to be seen, the junction between the glacial sandstones and the older basalt is a straight line that may be traced over the hill, for about a mile in length and at least 300 feet in vertical height. Just before reaching the bed of the Korkuperrimul, it is intersected by another fault, D, running south-easterly.

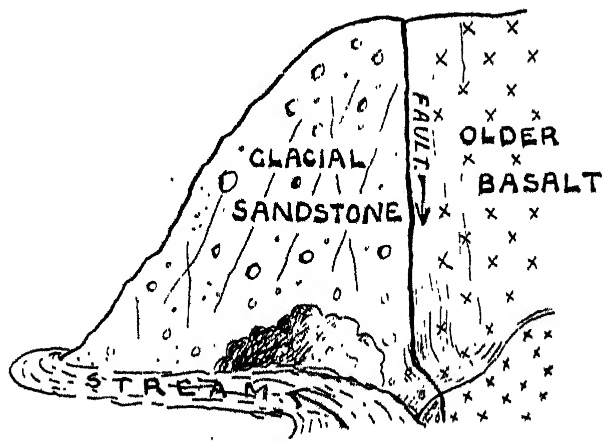


Fig. 11—Fault section exposed in cliff on right bank of the Korkuperrimul Creek, near the letter D. Fig. 10. The older basalts are let down against Permo-carboniferous glacial rocks.

The fault marked C probably continues westward, but since it there cuts through older basalt alone, it is not easy to follow. Where it would cross the Korkuperrimul creek, there is some evidence of its continuation through the older basalts on the right bank. The Korkuperrimul does not quite follow the fault line, D, but lies more in the older basalts of the western side, and in its bends provides conclusive sections of this fault. Going down the creek, we find a steep cliff of glacial on the left bank where the Korkuperrimul has taken a sweep in that direction; at both ends

of this cliff there is evidence of the fault D, older basalt lying against the glacial with an almost vertical junction; the section more upstream is soil-covered, but quite clear, the lower one is bare, and shows the decomposed basalt and glacial sandstones with a steep line of contact.

Continuing this line down-stream, however, an excellent section is found. Where the fault D crosses the Korkuperrimul, just above the letter D in Fig. 10, a cliff section, 20-30 feet high, shows the junction as depicted in Fig. 11. This last-mentioned fault increases in throw towards the south; at the north end a small cliff of glacial, with overlying basalt, occurs in the creek on the left bank.

(f) *Other small Faults.*—The preceding faults comprise all those of which the evidence is held to be satisfactory. As already mentioned, it seems undoubted that certain areas, especially the Ballan sunkland, structurally consist of a mosaic of faulted blocks. Mr. Baragwanath, who is at present engaged in a geological survey of the parish of Gorong, etc., has a good deal of evidence pointing in the same direction; much of this the writer has had the pleasure of examining with him in the field. The evidence for the faults is mainly provided by the older basalt and glacial beds, and many of them are suspected to be of the nature of the Bald Hill Fault.

(iv.) *Previously demonstrated Faults.*—These are dealt with as:

(a) Selwyn's Fault and others.

(b) Faults near Geelong. .

(a) *Selwyn's Fault.*—This very extensive and dominant fault (see h, Fig. 5, for plan), some fifty miles long, and with its chief down-throw (over 1700 feet) to the west, was first mentioned by Selwyn in 1857 (ref. 27), and has been frequently referred to since. In a map of Australia's Tectonic features (ref. 12) a north-south fault is shown cutting through Port Phillip, and hading west; it is labelled "Sorrento fault," and may refer to the one now being discussed.

What is believed to be the northern continuation of this fault has more recently been mapped by Morris (ref. 38), who states that the down-throw of this fault (referred to by him as the Montrose fault) is to the eastward, in the neighbourhood of the Dandenongs; he therefore regards the whole fault as "pivotal." The same writer has also published accounts of the Olinda fault (E.-W.), in the Lilydale area, and the Evelyn fault, hading east and parallel to the Montrose fault, about two miles further east.

The Croydon sunkland worked out on physiographic evidence by Jutson (ref. 33) has its locality suggested by a line, K, in the north-eastern corner of Fig 5. Regarding Selwyn's fault, it may be mentioned, as of physiographic interest, that where the line cuts across the granite mass of Arthur's Seat, it has left a straight and clean-cut boundary for some two miles, and in the resistant granite this face has been wonderfully well preserved (see Military Survey's Sorrento Sheet).

Mr. Chapman's evidence (ref. 8) from the famous Sorrento bore, shows a down-throw to the west of over 1700 feet. In a letter regarding the palaeontological evidence of the Sorrento bore (on the down-throw side of Selwyn's fault), Mr. Chapman writes:—"I think that here we have perhaps the oldest piece of evidence of Kainozoic faulting, which may date back to the Oligocene, for in no other way can I see an explanation of the great thickness of sediments of Balcombian age in the Sorrento bore, which maintains a fairly equable bathymetric aspect throughout. And here the movement probably continued till Pleistocene times, and the area may be subject to fits of weakness and collapse even at the present day." The fault is shown in section, Fig. 12, as the eastern boundary of the Port Phillip sunkland.

(b) *Faults near Geelong.*—Dr. Hall (ref. 28) mentions an east-west fault bounding the northern face of the soft Jurassic mudstones of the Barrabool Hills (see g, Fig. 5). At right angles to this fault there are apparently two other short ones, with a high ridge (horst) between. Dr. Summers and others have made investigations concerning these faults, and the evidence is generally accepted as conclusive; nothing as far as known to the writer has been published concerning them (except ref. 28). That to the west is commonly referred to as the Orphanage hill fault, and runs through near the cement works, meeting the Barrabool hills fault about Queen's Park, and forming the triangular "let-down" basalt plain between the junction of the Barwon and the Moorabool. The eastern one (Fig. 5) is believed to be marked by a low scarp that runs nearly north-south through Lovely Banks. This line is very clearly delineated on Quarter Sheets 19 S.E., 24 N.E., and 24 S.E., and is about fifteen miles long. (See also ref. 46.)

(v.) *Suggested Fault.*—We may be permitted to leave the domain of more or less demonstrated fact, in order to indicate a line that suggests itself as being a significant structural feature in the physiographic evolution of this area. It will be referred to as the Doran-Egerton line.

The writer, travelling a good deal over the country south of Ballarat, has been struck by the dominance of north-south Ordovician ridges rising above the newer basalt sheet. The important and isolated Ordovician heights of Mt. Doran, Mt. Egerton, and Haydon's Hill—giving a line sixteen miles long running a few degrees east of north, has already suggested itself to various observers as a relic of the eastern up-tilted edge of a fault block. Thy physiographic evidence seen in frequent cross-country traverses in that area, backed by the contours shown in the field notes of the Commonwealth Military Survey, point towards this line marking a fault, parallel with those of the western highlands, as demonstrated by T. S. Hart (ref. 22).

(vi.) *The Sunklands.*—Little remains to be said concerning the great relatively sunken blocks of the Werribee area, which have already been frequently referred to. They are :—

(a) The Port Phillip Sunkland.

(b) The Ballan Sunkland.

(a) *The Port Phillip Sunkland.*—This has been referred to mainly as block E, though it of course extends beyond that block, embracing Port Phillip Bay. The northern limits of this area have not been investigated, except along the base of the Gisborne highlands, but the east and west limits are the Rowsley and the Selwyn Faults respectively. This relatively sunken block has given Victoria her two chief harbours, the sites of her early settlements, and of the capital city. The known limits are set out in plan in Fig. 5 and a section drawn from the 50 foot contours of the Military Survey is shown in Fig. 12, with the geological structure also marked in. The economic aspects have been already referred to under the heading of general description of the area.

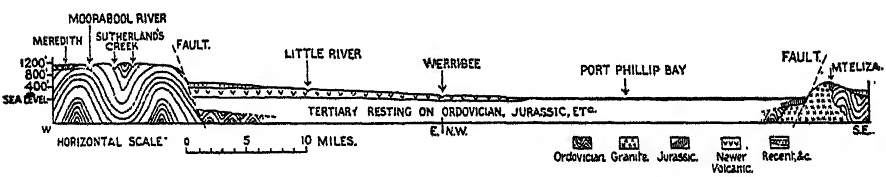


Fig. 12.—Section across the Port Phillip Sunkland, from Meredith to Mount Eliza, showing geology and relief.

The section (Fig. 12) is drawn from Meredith, east to the town of Werribee, and then south-easterly to Mt. Eliza. It will be seen that the sunken portion slopes gently from west to east, the eastern portion, Port Phillip, being below sea level. The depths of the

Bay were slightly exaggerated in the figure in order to show that feature. The eastern boundary, Selwyn's fault, has been proved to be of greater age than the western boundary, the Rowsley scarp. Probably later movements have taken place on the east (ref. 8), and earlier ones on the west, although the latter have so far not been demonstrated.

(b) *The Ballan Sunkland.*—This area has also been previously described, as regards its economic and other aspects, having been referred to as block B. It is bounded on the north by the Greendale fault, and by a fault of probably similar age on the south, shown in Fig. 5. On the west the suggested boundary is the Doran-Egerton line, beyond which no glacial nor older basalt is preserved as far as known. In the east, the Ballan sunkland is bounded by the Rowsley fault, and stands higher than the Werribee plains; it may be known alternatively as the Ballan Plateau, a distinct geological unit in the larger Ballarat Plateau (refs. 20, 21). A

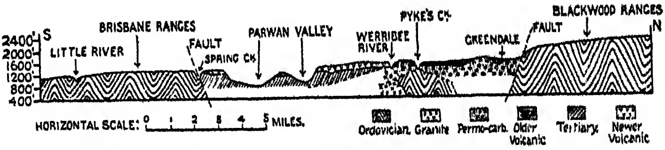


Fig. 13.—Section across the Ballan Sunkland, showing geology and relief. Note the complex structure of the let-down block. In these sections the geology is necessarily to some extent diagrammatic.

section drawn to scale from the Military Survey maps (50 foot contours), with the geological formations diagrammatically suggested is shown in Fig. 13.

(vii.) *Final conclusions as to age.*—We see then that there are here two dominant and undoubted faults with fairly clear age relationships, and these should prove important factors in arriving at the precise period of uplift of our highlands, a matter which we have already discussed. The writer is led to the conclusion that—

(1) the peneplanation was completed about the time of the Older Volcanic period.

(2) Differential uplift took place subsequently with extensive faulting.

(3) Dissection, etc., continued up to the Newer Volcanic period, closely subsequent to which a further series of uplifts occurred, slowly bringing the main highlands of Victoria to their present general levels.

(4) The dissection already begun was then continued, except where interfered with by the newer basalt flows. In the latter cases new stream valleys were carved out, as detailed in a later section.

An important and interesting corroboration of portion of these conclusions, reached independently by Mr. Chapman (ref. 8, pp. 401-407), has been recently published by that gentleman. His evidence is purely stratigraphical, based on a knowledge of richly fossiliferous beds, and connected with the first-proved extensive fault in this State—that known as Selwyn's fault. A differential movement of 1700 feet is referred to, and a positive elevation of the up-throw side is believed to have taken place about the time referred to in this paper as the Older Volcanic period. This is approximately the age given for the Greendale, Spring Creek and other leading faults in the Werribee area.

While the two great uplifts in the Werribee area—the Greendale uplift, and the Bacchus Marsh uplift—are referred to certain ages, it is not assumed that the fractures themselves really originated then. Rather is it possible that extensive movement had taken place along them prior to that long "still-stand" that produced our peneplain. It is generally accepted that great faults are probably not developed by a single movement, but by repeated displacements, separated maybe by long intervals of time (Salisbury "Physiography."). Professor David (ref. 12) shows, in a generalized section, the Victorian permo-carboniferous preserved by assumed faults, and such movements must be accepted to some extent to account for the preservation of such soft and friable rocks during planation. To come to a much later date, there are at the Ballarat School of Mines interesting and reliable records of an abrupt lift of 23 feet met with in an auriferous sub-basaltic deep lead, near Smeaton, compiled by the Manager of the Mine concerned, Mr. J. McKenna, 1882; similar records exist from neighbouring mines. Again, there seems no doubt that movement is still proceeding at an extremely gentle rate. Interesting positive evidence of this has been noted by the writer in the New Normanby mine, at Ballarat, north west of the Werribee River area. In the western cross--cut at the 1500 foot level of that mine, there were some half-dozen small faults noticeable, within a few yards, totalling a downward throw of over 8 inches. This movement occurred in less than two years. At the time it was noticed, this was the deepest level on the field, so that the movement must have been of a general nature. The faults here ran along a north-south line.

These were pointed out to the writer, and the particulars kindly supplied by Mr. W. Baragwanath, of the Victorian Geological Survey.

East-west movement has also been reported as taking place in recent years. Mr. W. Bradford, of Ballarat, tells of a case of a shift of about one-foot laterally (E.-W.) in a drive in the Star of the East mine, Ballarat, at the 1300 foot level, subsequent to putting in the drive; the particulars of this movement were communicated by him to the Mines Department. Taylor (ref. 52) regards the great N.-S. Lake George fault scarp of New South Wales as being formed 20-30,000 years ago.

J. T. Jutson, in a paper on the older basalts of Greensborough and Kangaroo Grounds, suggests that some of the Victorian basalts are intermediate in age between the older and newer basalts. As far as our present knowledge goes, this series is much less important and extensive than either of those of the two other periods. In this paper the two chief periods—"older basaltic" and "newer basaltic"—are used as benchmarks of time, with certain cautions already laid down, and the intermediate series is not referred to. As investigations proceed into the many obscure

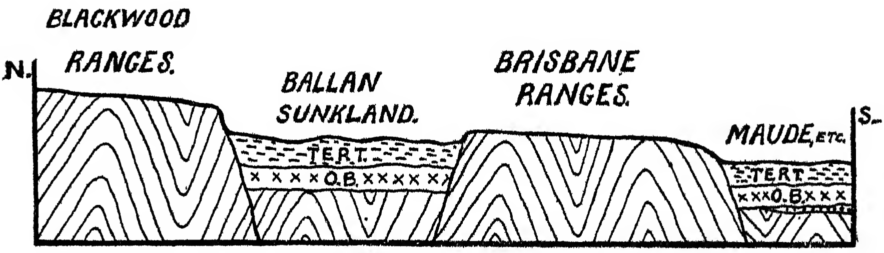


Fig. 14.—Diagram to illustrate the probable relationship of the Older Basalts (O.B.) and tertiaries (Tert.) of the Ballan Sunkland and of Maude to the neighbouring ordovician (folded) blocks.

points of our Victorian geology, demonstrated physiographic facts will no doubt aid the petrologist and the palaeontologist in the elucidation of the problem of the exact distribution of these three basaltic series and their true places in the time-record. For instance, the known structural features of the country from the Divide to the "Great Valley of Victoria," through the Parwan Valley and Maude, strongly suggest that the older basalts and the overlying tertiary beds of the Bacchus Marsh area may be correlated in time with those of Maude, although the former are freshwater and the latter partly marine. Both series are preserved in

troughs that we may reasonably believe to have been formed at the same period. The idea is diagrammatically illustrated in Fig. 14.

(c) *The Newer Volcanic Sheet and its Effects.*

Fig. 15 has been drawn to show the extent to which the newer basalt has affected the physiographic features of this area. This map of course shows the minimum extent of the basaltic sheet—it has in many parts been hidden by later alluvial deposits, while in other places it has been eroded away. With the exception of the high block of the Blackwood and Lerderderg Ranges, with a small portion of the Gisborne highlands, and most of the Brisbane Ranges, the basalt sheet must have practically covered the whole of the area. The Blackwood Ranges seem to have escaped on account of their being then much higher than the general low even surface of the remainder of the area. Even so we have various small areas of lava on this block, with evidence that these patches were once more extensive—as at South Bullarto, Wuid Kruirk, Mt. Wilson, Blakeville, Upper Werribee, Green Hills and Mt. Blackwood itself.

It will be seen that the task of deciphering the buried physiography is a very difficult one. The well-known figure of speech comparing such a task with the deciphering of a palimpsest is particularly applicable. The old stream courses have been almost entirely obliterated, and only at rare intervals do we discover relics, mainly where the post-basaltic streams have cut through the volcanic sheet, exposing something of the rocks below. To use the words of one geological writer (ref. 32) :—" Like a moss-grown inscription upon a slab of marble, though veiled it may be deciphered." The writer must confess that many of the problems concerning the buried rivers remain unread, but some important evidence has been collected.

It may be first stated that the surface before the newer basalt flows was of low relief, with one or two exceptions. The Greendale and probably the Gisborne scarps were in existence, as were the wide valleys of the Lerderderg and Gisborne creek. One or two monadnocks, as the You Yangs and the much lower granitic portion of the Anakies stood above the general level, as also did a low rounded dome of Ordovician slates and granite in the neighbourhood of our present Werribee gorge. Elsewhere the relief was not marked, since apparently blocks B, C, and E must have been almost at sea level. In the raised blocks A and D, as mentioned, the relief was much more distinct, the dissection of the lifted peneplain in those areas having by this time been well started. Mr. Charles C.

Brittlebank (ref. 6) mentions old channels filled by newer basalts, 170-350 feet deep. That gentleman has kindly taken me to see each of these various interesting sections of old river valleys that he has discovered, in the neighbourhood of "Dunbar," Myrniong.

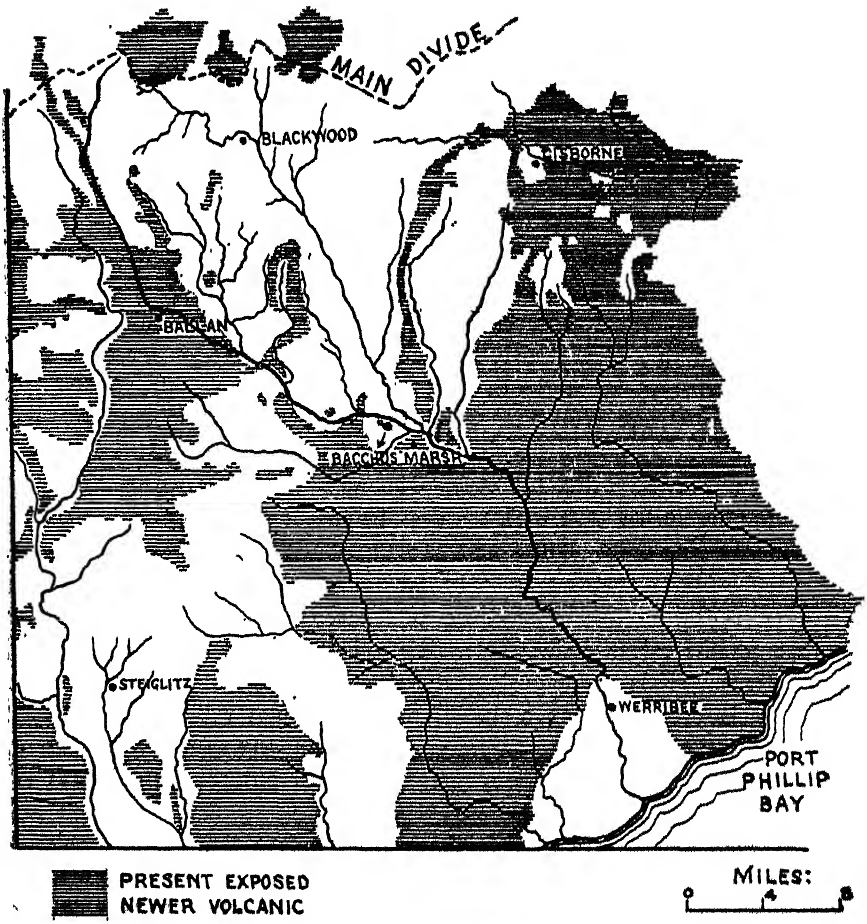


Fig. 15.—Map showing the extent of the Newer Basalt lava flows, as at present exposed The basalts were originally more extensive, but in places have been eroded away, and in the other places obscured by deposition of alluvial materials (Section VIII c).

Added to these are others found by the writer, and altogether they enable an interesting part of the ancient river courses to be well mapped out. This will be dealt with under the heading of buried rivers.

While we see that over an area of low relief the basalt spread as a great level sheet, filling the valleys and covering the low dividing ridges, this was not the case in the higher country where deeper valleys existed. In at least five places we have the volcanoes originating in higher areas, and sending their lava flows as long tongues down the existing valleys.

In some cases this infilling resistant tongue caused the formation of two new streams, one on either side of the basalt flow. Such streams run closely parallel for good distances, and are very common in many parts of Victoria—e.g., Goodman's and Pyrete creeks, upper parts of Myrniong and Korkuperrimul creeks, etc., etc. It is so characteristic a feature that for the purposes of our

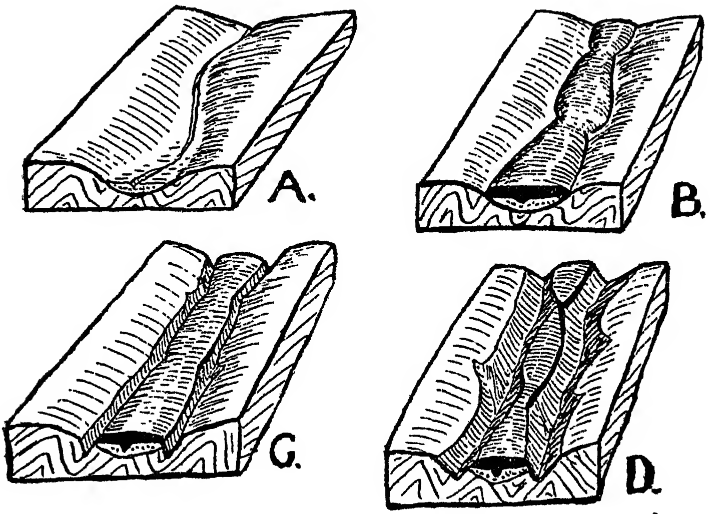


Fig. 16.— Diagrams to illustrate the origin and progressive erosion of "Twin Streams." In connection with the Newer Basalt flows in Victoria, such erosion has rarely advanced beyond the stage shown in D.

local geography, it might be well if a special name were used for descriptive purposes. On account of the similarity of their nature, and the contemporaneity of their origin, it is suggested they be called "twin streams" (see Fig. 16a, b, c. d).

The basaltic tongues referred to are:—

i. From Leonard's Hill and other points thereabouts, long tongues came southward down the valley of the upper Werribee, through Korweinguboora, etc. (It is possible that some "older basalts" occur here also.)

ii. From Bald or Larkin's Hill, and from a point near Blakeville, a tongue came down in an old stream, crossing the Greendale fault north of Mt. Steiglitz.

iii. From Greenhills, a tongue ran down what is called Greenhills Creek, a small tributary of the Korjamumnip. This flow did not reach to the edge of the scarp.

iv. From Mt. Blackwood, a tongue came down an old river that flowed midway between the present Myrniong and Korkuperrimul—referred to later as the "ancient Myrniong" (see Fig. 21).

v. From Mt. Bullengarook a long tongue came down between what is now Goodman's and Pyrete (or Coimadai) creeks. This has been previously described (ref. 43) as the "ancient Bullengarook" river. (See Fig. 22.)

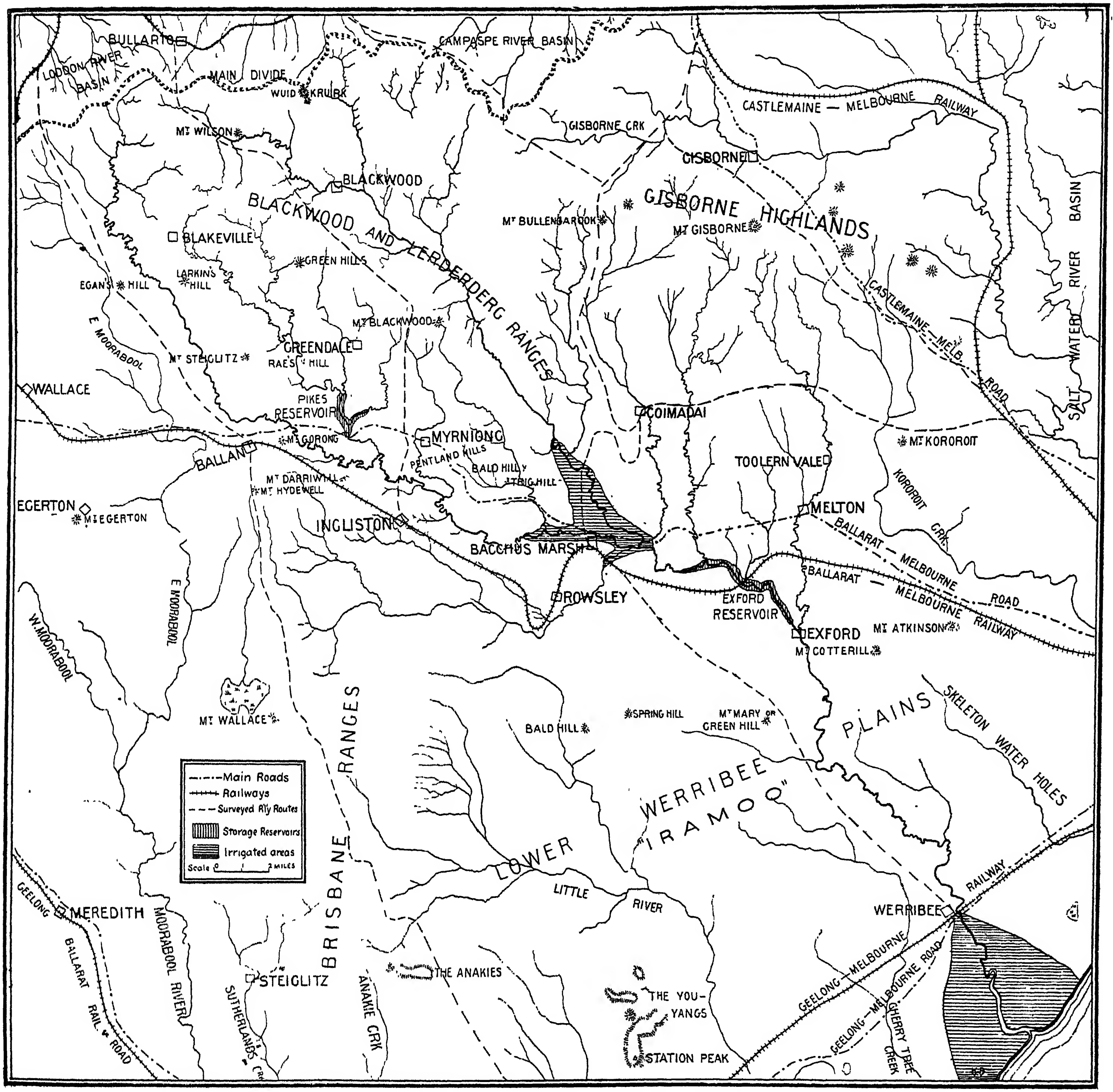
The general effect, therefore, especially on the less elevated areas, was obliteration. A new series of streams was formed on this new surface, twin streams were originated on the higher surfaces, old and uninterrupted streams, such as the Upper Lerderderg, were forced to find new courses in their lower parts. All these streams were rejuvenated, since a basaltic sheet is quite analogous in effect to an uplift movement. Closely following, or in the later stages of, this volcanic period, however, there was a great general uplift, in addition, of all the blocks in the area except the Lower Werribee plains (block E). The streams were thus doubly rejuvenated, and were given a scarp from which to commence their gorge-cutting and general work of denudation.

Even on the lower plains there was a certain amount of rejuvenation, due to the basalt sheet; thus we find the Werribee and other streams now flowing in narrow young gorges averaging 100 feet in depth. (Fig. 27.) It was above the scarp, however, that the most severe action took place, and there we have the deeper gorges of the Upper Little River, the Parwan, the Werribee, the Lerderderg, etc. This gives us, broadly speaking, the effect of the newer basaltic eruptions. Economically, of course, the effect of the basalt flows is very great.

IX.—Detailed Account of the Physiography.

(a) *Ranges and Hills.*

(i.) *The Main Divide.*—As will be seen from Plate XI., the main Divide of Victoria does not enter very largely into the area under discussion. The head waters of the Werribee and of the Ler-



General Map of the Werribee River area, showing the chief centres of population, with main roads and railways, other surveyed railway routes, streams, etc. The main localities mentioned in the paper are shown in this map.

derderg have their rise there, as also have many other Lerderderg tributaries, such as Split Tree, Frenchman's, Wild Dog, Sargonne (? Sardine), Clear Water, etc. The remaining Northern boundary of the Werribee basin is the Gisborne ridge, which is separated from the main Divide by the eastward trending valley of the Gisborne Creek, a tributary of the Saltwater River.

The nature of the Divide may perhaps best be followed by descriptions from various viewpoints along its course in this area. On the whole it stands up very little above the general level of the lifted peneplain block which it traverses. The three highest points visited by the writer are each due to the accumulation of volcanic material. These points are:—

(a) Leonard's Hill.
(b) Old Bullarto.
(c) Wuid Kruirk.

(a) Leonard's Hill is a rounded volcanic cone clothed with fertile soil, standing at an elevation of 2500 feet (aneroid). It is right on the Divide, and close to the railway station of Leonard (Ballarat-Creswick line). To the north rise the head waters of the Jim Crow Creek, a tributary of the Loddon, while on the southern side are small tributary gullies which lead to the Werribee and the Eastern Moorabool. Fine views are obtainable; to the east the Divide continues in densely timbered Ordovician ranges, well seamed by gullies of very moderate relief. To the West, this feature has a similar aspect, except that a high timbered ridge occurs, and partly shuts out the view; far to the west, however, may be seen the dim blue outlines of the parallel N.S. ranges of the highlands of Western Victoria (ref. 22).

The aspect of the Divide, where it lies in the Ordovician and appears most likely to have been uninfluenced by the newer basalt flows, is what one would expect to find where two sets of streams, flowing in opposite directions, were competing for territory by headward erosion. Possibly the predisposing causes of the two opposite flowing sets of streams already existed on this block of upland itself. On the other hand, the factor which gave the streams their present directions might have been the let-down country to the N. and S.; creeks and rivers would then head back into the highest block, almost independently of the surface-levels of that block. The lifted block may even then, of course, carry on its surface a set of stream channels which existed on the ancient peneplain.

It would seem probable that the old uplifted block originally had a more extensive northern slope than is the case at present, so that longer consequent streams on that slope would be competed against by vigorous streams heading back from the south. The southern rivers, having a markedly shorter course to the sea, have a great advantage in average grade, and are the more vigorous streams. Thus it was found all along the Divide in this area that the deeper valleys and the more vigorous erosive work was being done on the south, with consequent northern migration of the Divide.

Four miles further eastward (slightly N.E.) is another area of volcanic material, at Bullarto. The intervening Ordovician ranges are almost uninhabited, and no roads cross that area. We must therefore travel northward to the mining town of Daylesford and southward again to Old Bullarto. Both roads lie mainly along converging tongues of basalt, which preserve old north flowing valleys.

The rich agricultural village of Old Bullarto lies right on the Divide, a mile or two south of the railway station of new or north Bullarto. The latter station long enjoyed the distinction of being the highest in Victoria (2452 feet). An old railway survey, coming across the ranges from the south, crosses the Divide at Old Bullarto (2610 feet). The basalt flows which here form the Divide are not extensive, but are highly cultivated, and crown the range with rich farms. To the north the Wombat Creek and Kangaroo Creek flow to the Loddon, both rising within the township, and having here low, swampy courses, although deepening further north. In this township also we may find the sources of the two main rivers of our area—the Lerderderg and the Werribee.

Here again we find the more vigorous work being done by the southern streams, especially by the Lerderderg. The actual source of the Werribee River is somewhat swampy, though deepening rapidly further south. A small N.-S. ridge divides the Werribee from the Lerderderg, and the latter stream is conducting a very vigorous erosive campaign, forcing the Divide to the north.

To the east of Bullarto there is a high timbered hill, locally called Coghlan's Hill, and apparently of Ordovician. Beyond that, lava flows, mainly extending to the north, again form the Divide (Fig. 15); the highest point of this volcanic area is Wuid Kruirk (2800 feet), also the highest point in the Werribee area. Magnificent views are obtainable from this Mount, mainly to the southward, right across the great uplifted peneplain blocks, boldly cut

through by the valley of the Lerderderg, and beyond again to the Werribee plains, and thence to the sea. Looking south, the line of the Greendale fault can be clearly detected, running east and west, and separating the heavily-timbered ranges from the open country beyond. While the sides of this hill (Wuid Kruirk) are clothed with timber, the summit is a bold, bare bluff, and the views in all directions are thus unimpeded.

The Divide, which runs nearly E.-W., from Old Bullarto to Garlick's Lead (Newbury), now turns sharply N.E., no doubt due to vigorous work being done here by a strong S-flowing tributary of the Lerderderg. Ferguson (ref. 18), who examined the sub-basaltic alluvials at Garlick's Lead, found evidence therein of a northern migration of the Divide. The north-pointing salient east of Wuid Kruirk is in Ordovician rocks, and the Divide turns southward again at the volcanic area of East Trentham. Thence it continues south easterly in Ordovician to the head waters of the Campaspe, and so out of our area. There is a low pass through the Divide at the point separating the Campaspe from Gisborne Creek, and through this a survey has been made for a projected Holden-Trentham railway; this survey crossed the Divide at 2376 feet. The somewhat flat, and occasionally swampy, valleys of the Campaspe and Gisborne Creek, near their sources, contrast strongly with the steep-sided valleys of the Lerderderg and its tributaries.

While examining the Divide in this area, unsuccessful effort was made to find evidence in favour of Gregory's "Primitive Divide" having at all affected the present topography. While touching on this matter the writer would wish, only for a moment, to enter into the controversy regarding this postulated ancient range.

Professor Gregory (ref. 20), to whose inspiring work Victorian physiography owes so much, appears to base this theory of the "Primitive Mountain Chain," largely on the linking up of selected masses of Plutonic rocks, the exposures of which are believed to have an east-west trend across the highlands of Victoria. T. S. Hart (ref. 22, p. 264, etc.), advances strong evidence against the correctness of this hypothesis.

It is to be expected that we could get the most correct reading of our physiographic and geological history by linking up both with the known facts of South-Eastern New South Wales. A sketch (Fig. 17), has therefore been prepared to show the actual distribution of the plutonic masses of the south-eastern part of Australia. As might be anticipated, this sketch shows that the general trend of he pluntonic masses is similar to the general trend of the axes of

the great folding movements that affected our lower palaeozoic rocks. The plutonics of South-Eastern New South Wales are seen to be definitely elongated along north-south lines, strikingly shown in

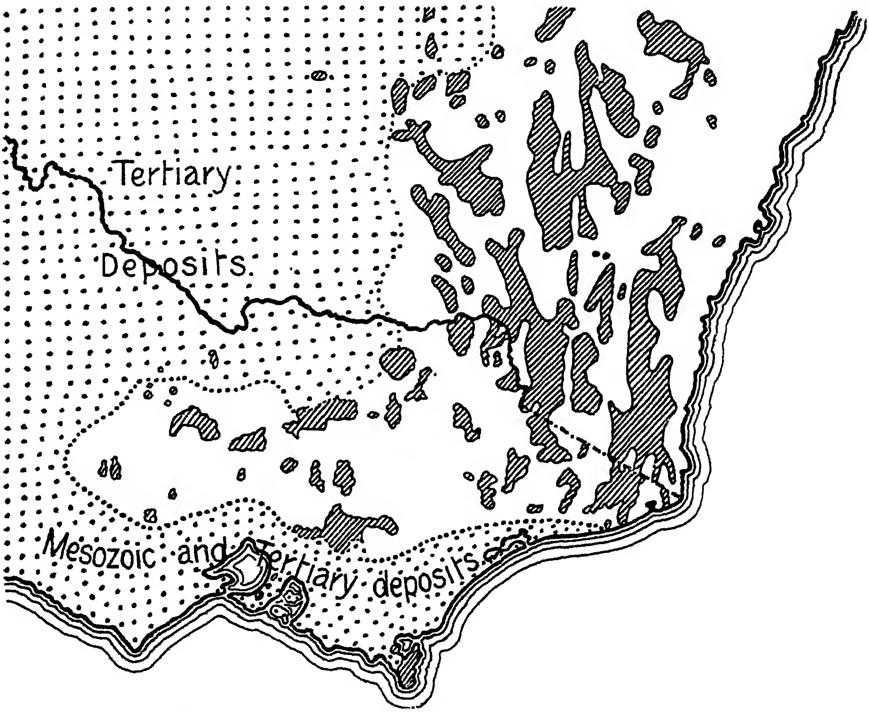


Fig. 17.—Map showing the distribution of granite exposures in South-Eastern Australia, and indicating the predominance of elongation along North-South axes. In addition to the covering of younger sediments shown dotted, other granite areas are doubtless obscured by rocks of Carboniferous and subsequent ages.

the latest geological map of that State. In Victoria the occurrences are fewer, with a greater area obscured by later sediments and volcanics; still, a general elongation in a north-south direction is observable. Had the sketch been continued southward to include Tasmania, this point would have been further emphasized, especially in the better known granitic areas of the north-eastern part of the island. The great mass of the Strathbogie ranges in Victoria certainly appears to trend east-west, but close observation shows that it may not always have been of this shape. To the north this mass is of gradually lower relief, and is finally covered over by the tertiary deposits of the "Murray Gulf," etc., while on the

south, the nature of the junctions strongly suggests that part of the mass had been faulted down. Similar observations may be made regarding other masses. In the case of the great horeshoe-shaped Harcourt exposure, and many others, the marginal lines trend north-south just as much as they do east-west. These plutonics certainly do not appear to present sufficient evidence for the assumption of a great continuous east-west range of mountains.

T. S. Hart, who has given his attention for many years to the question of the origin of the Main Divide, stated in his paper before the B.A.A.S., at Melbourne, 1914, (ref. 23, p. 443), that "the actual intrusion of the granitic rocks has taken no part in forming the present Divide."

The fact that the intrusion of our pluntonics is known to have been wholly palaeozoic (? Devonian and earlier), and associated with intense folding along north-south lines, would also suggest that any mountain ranges associated with those plutonics were also palaezoic, and with a north-south trend.

(ii.) *The Block Ranges.*

(a) *The Blackwood and Lerderderg Ranges.*—These ranges constitute the whole of block A (see Plate XI. and Fig. 2), and are bounded on the west and north by the Werribee River and the Main Divide respectively; on the east and south are the well-defined scarps of the Rowsley and Greendale faults. Either of the two names given above is used to designate these ranges, the former being derived from the prominent volcanic hill (Mt. Blackwood), or from the once thriving goldfield of that name, situated in the northern part of the ranges. The alternative name is due to the Lerderderg River, which has carved a deep valley right through the whole block from north-west to south-east. As already pointed out, these ranges are almost wholly of hard, resistant, folded slates, sandstones and quartzites of Ordovician age, levelled to a peneplain by river action, and later uplifted and dissected. The average level is about 2200 feet.

The general plan on which dissection has proceeded is set forward as under. It must be remembered that most of these ranges and streams are unsurveyed, and most of the surveys which do exist are scrappy and old (as we count time in Victoria). More recently the mining area of Blackwood, and the saw-milling village of Blakeville have been surveyed, while the Commonwealth Military

Survey has published contour plans, which extend over the southern portion of the block. An effort has been made (Fig. 18) to indicate the general direction of the ridges and valleys in this lifted block. As already mentioned, the Lerderderg and its tributaries have done nearly all the work. Between this stream and the others concerned, residual ridges occur, and help to provide the easiest regular "tracks" across the ranges.

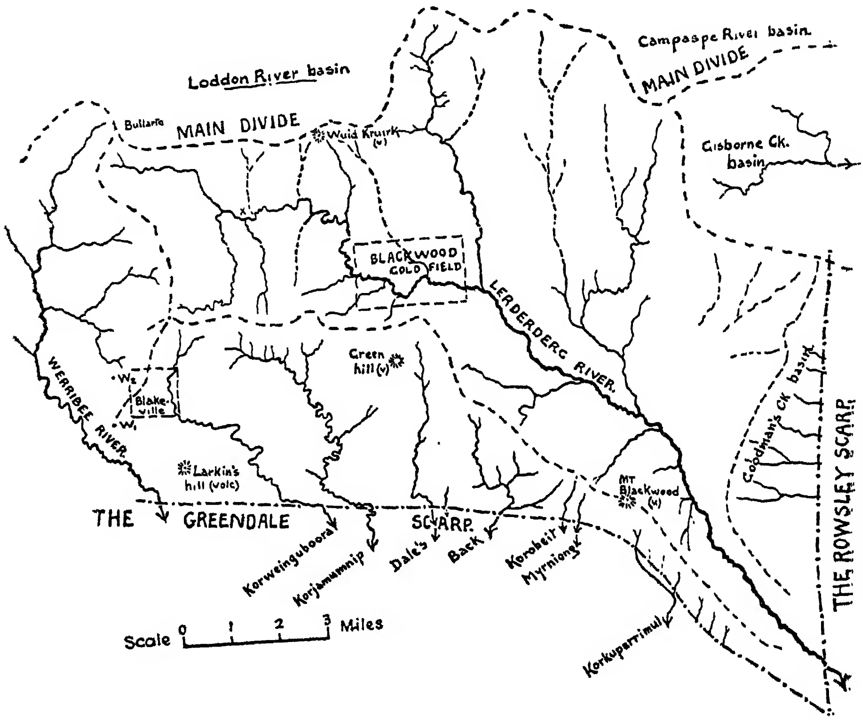


Fig. 18.—Streams and Divides of the Blackwood and Lerderderg Ranges. (V) — volcanic hills.

It will be seen that there is a high knot of country to the north of Blakeville, from which streams flow in all directions; an irregular ridge connects this with the Main Divide at Bullarto, forming a north-south divide between the Lerderderg and the Werribee. Another long ridge runs east and south-east beyond Mt. Blackwood, separating the Lerderderg from the south-flowing tributaries of the Werribee—the Korweinguboora, Korjamumnip, Dale's, Back, Korobeit, and Korkuperrimul Creeks. The writer's conception, which will be elaborated when dealing with the individual streams,

is that the Lerderderg is not only the dominant stream of the whole Werribee basin, but is also the most ancient, and probably inherited its course from an ancestor which existed on the ancient peneplain. While the long northern tributaries of the Lederderg appear to have maintained their courses, and increased their territory northward (see Fig. 18), new post-uplift streams on the east and south, with steep grades and softer rocks to help them, appear to have captured part of the old Lerderderg basin.

(b) *The Brisbane Ranges.*—Here again we have a huge uplifted block of folded Ordovician, structurally and lithologically quite similar to the Blackwood ranges, and similarly containing a once-important, centrally-situated mining field (Steiglitz). The boundaries of this block are not clearly defined, and the name is generally applied only to the eastern part, the western portion being in part covered by alluvium and basalt flows, cut through by the deep gorge of the Moorabool River. The general level of the block is about 1200 feet, sloping towards the south and west. The northern boundary of the ranges is the Spring Creek, while on the east is the remarkably well-defined scarp of the Rowsley fault.

Davis (ref. 16) says:—"The simplest and most manifest element of faulting along a mountain base is a straight or but moderately curved base line, passing indifferently across or obliquely along the structure of the mountain mass, which rises rather abruptly and continuously on one side, while a sloping plain of waste is spread out on the other." The field evidence along the whole east front of the Brisbane Ranges shows that here we have a feature exactly fulfilling these conditions. This steep portion is dissected by numerous tributaries of the Little River, while the southern half is deeply cut into by the various branches of Sutherland's Creek.

(c) *The Ballan Plateau.*—This structural unit is what we have so far referred to as block B, or the Ballan sunkland. Although a sunken area with reference to the Brisbane and Lerderderg Ranges, it is relatively lifted about 1000 feet above the plains of the lower Werribee—the Port Phillip Sunkland (see block diagram, Fig. 3), and since the main lines of communication between Melbourne and Ballarat give an emphasis to the sudden rise above the scarp face. it is more popularly known as part of the "Ballarat Plateau." Structurally, it is of much greater complexity than either of the two blocks already described. It would appear to have been greatly faulted within its own boundaries, and consists of Ordovician slates, etc., glacial sandstones and conglomerates, older volcanics,

middle tertiary sands, clays, etc.—all largely covered by the later volcanic lava sheet.

It is deeply cut into by the Parwan, the Werribee, and minor streams in the east, and by the Moorabool in the west. These streams however have not carved the area into a maze of ridges, as is the case in the Blackwood and Brisbane ranges; a result largely due to the preserving influence of the newer basalt sheets. An isolated patch of extensively dissected Ordovician and granite occurs to the south of Werribee Gorge, where small tributaries of the Werribee and Parwan have done a vast amount of work; this area was never covered by the newer basalt sheet. The nature of this locality is strikingly seen from the railway line between Bacchus Marsh and Ingliston, since the line travels along somewhat above the general level of the isolated patch of timbered ranges.

(d) *The Gisborne Highlands.*—The western portion of this high area is Ordovician, and that rock also probably underlies the whole of the eastern part, the present surface of which is newer volcanic. The Ordovician at the head of Pyrete Creek stands at a distinctly lower level (2-300 feet) than the ranges immediately to the west (block A), but they are some 7-800 feet higher, on the average, than the volcanic portion of the Gisborne highlands further eastward. The general levels of this "block" are much less as we go eastward, grading down to that generally lower portion of the Victorian Highlands that marks the "Melbourne-Echuca line" referred to by Taylor (ref. 52) as the Kilmore geocol.

(iii.) *Residual Hills.*

(a) The *You Yangs.*—The name of this impressive range is evidently a corruption from the recorded aboriginal name of Wurdiyouan. It is historically the most interesting point in the area, on account of its ascent by Matthew Flinders in 1802.

Fig. 19 shows the outline of this very familiar landmark, drawn to true scale and projected from the contours of the Military Survey. The mass is wholly granitic, although a small outcrop of the intruded Ordovician slates occurs at one place. The You Yangs must have formed a striking monadnock on the ancient peneplain; there is no doubt that it owes its origin to the highly resistant nature of the rock of which it is formed. Alluvium and lava flows surround the base, and the apparent height of the mount is exaggerated by the extremely level nature of the surrounding plains. These hills have already been dealt with in complete

detail by Professor Skeats (ref. 46). A low and irregular granitic ridge continues from the You Yangs to the Anakies, and forms the southern boundary of the Little River basin.

Fig. 19.—Contour of the granitic monadnock of the You Yangs, as seen from the South-East or North-West, true scale, projected from the contours of the Commonwealth Military Survey.

(b) *The Anakies.*—These are only in part residual in origin, since the most impressive portion of the group known as the Anakies consists of high accumulations of volcanic materials. The group loses in impressiveness from its position on the lower of two neighbouring blocks of country.

The early recorded name of the Anakies was Anaki or Anikai) You-wan. As the latter part of the parallel names was retained for the You Yangs, so has the first part of the name of this group come to be the generally accepted one. The granite portion of the Anakies is less than 1000 feet in height, and shows some fine large granite tors. Like the You Yangs, this hill was undoubtedly a monadnock on the ancient peneplain. No similar granites occur in any other part of the Werribee River area, as far as known. This granite appears to be much more resistant to erosion than are the granodiorites of the Werribee Gorge and elsewhere.

(c) *Trig Hill, etc.*—Here we may include a number of lesser hills that have been formed by the dissection following the recent uplifts. They are therefore very much younger features than the You Yangs and Anakies, having their origin subsequent to the newer volcanic period. A number of such hills occur, nearly all of them in the Ballan Plateau. Structurally, they show great variety, and provide interesting examples of differential erosion.

Among them we may specially mention Trig Hill, Pentland Hills, and "the Island"—all of which are due to the great valleys carved by the Werribee and Myrniong. Their tops are really portion of the fairly level block of the Ballarat Plateau. Trig Hill (sometimes known as Table Top), an important trigonometrical point, is well known to those who travel by rail through Bacchus Marsh. It stands on the left bank of the Werribee, about a mile above the point where the Korkuperrimul enters that stream. As will be seen from the sketch it has a complex structure of older basalt, tertiary beds, and newer basalt, the influence of each formation being shown in the varying slopes.

The Pentland Hills are better known to travellers by road, the V-shaped valleys which have formed them being somewhat impressive in appearance. They mark an area of good pastoral country,

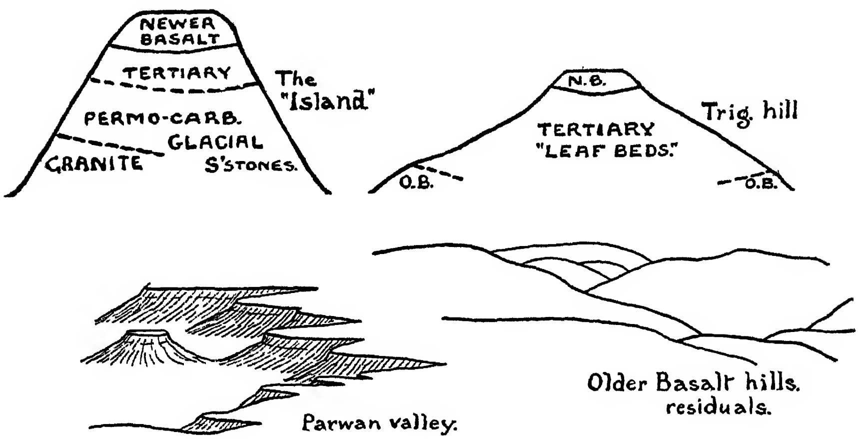


Fig. 20.—Diagrams and sketches of various residual hills in the Ballan Sunkland, as detailed in Section IXa. O.B.—Older Basalts. N.B.—Newer Basalts.

and were early settled; these hills were among the very few features of the Werribee area referred to by Brough Smyth (ref. 49). Professor David has also felicitously described them (ref. 13).

Close to the Pentland hills is "The Island," formed in the loop between the Myrniong and the Werribee, above their junction (see Fig. 36.) This feature is surrounded on three sides by deep valleys, and there is a low wind-gap on the fourth side. To use the phrase of Mr. C. C. Brittlebank, this part has been "thrice a valley and now a hill." The base is mainly glacial, and we may fairly assume a valley for the glacier. Above this formation tertiary leaf beds occur—probably fluviatile, giving us a second valley period. In these beds at a later date, was eroded the (third) valley of the "ancient Myrniong," now filled by newer basalt; resistant basalt now caps "the Island," and erosion on both sides has given us the "hill." The sketches shown in Fig. 20, indicate the structure and the different outlines resulting therefrom, so that no further description of this group of residuals is necessary. The sketches are mainly diagrammatic.

(d) *Mt. Wilson.*—This hill presented some difficulties to the writer. In the absence of any accurate and detailed surveys of the north part of the Werribee area, every available map that

included any portion of those ranges was closely examined for topographical data. This was done as a preliminary to the actual field work, and one of the few features noted on such maps was a Mt. Wilson, near Blakeville. On Ham's Map of 1847 (on a tracing by Mr. Barnard), this hill is shown, spelt Wilsone. The county plan of Bourke, and the large maps of the State also show it as standing to the south-west of Blakeville (see W_2 Fig. 18). The geodetic sheet that includes this area shows it as being north-west of, and close to, Blakeville (see W_2, Fig. 18). Among the complex maze of blue ranges there, the writer naturally expected to see this feature standing somewhat above the general level. This was not the case, and frequent enquiries from bushmen who knew the country well, pointed to the fact that while there was a well-known hill of that name in the ranges, it was in a very different position from either of those shown on the maps. The real Mt. Wilson lies about half way between Old Bullarto and Blackwood townships (roughly about X, Fig. 18), and is a residual, in the preservation of which lava flows appear to have played a part. It was noted from many points by the writer, but not visited. Mr. A. Blake, of Ballan, who knows all the Blakeville country thoroughly, has written confirming the writer's view that no Mt. Wilson exists where marked in all our current maps.

Volcanic Hills.

(a) The highest peak in the area, Wuid Kruirk (Blue Mountain), has already been described. Its real height as a volcanic hill is no more than 500 feet, the remaining 2300 feet being the height of the Ordovician block on which it stands.

(b) Next in order is Mount Blackwood (2432 feet). This hill stands almost centrally within the Werribee River basin, and is visible from practically every part of that area. Like Wuid Kruirk, the height of the volcanic portion is only about 400 feet, and Blackwood stand on the same uplifted block, close to the southern scarp. This will be clearly seen from Fig. 21, which shows a plan and section of the cinder cone, and the main lava flow therefrom. The dotted line in the section marks the general level of the old peneplain surface. There is very little trace of a crater. The old county map of Bourke shows the hill as "Mount Blackwood, or Myrniong." In a letter written by Mr. W. H. Bacchus in 1876 (ref. 59), he states: "Mt. Blackwood was then (1836) known as Clarke's Big Hill." In Major Mitchell's Map of

Australia Felix, 1836, the same hill is, however, marked as Mt. Blackwood (ref. 60). The back files of the Ballan Times record that the Mount was so named after one "Captain Blackwood, com-

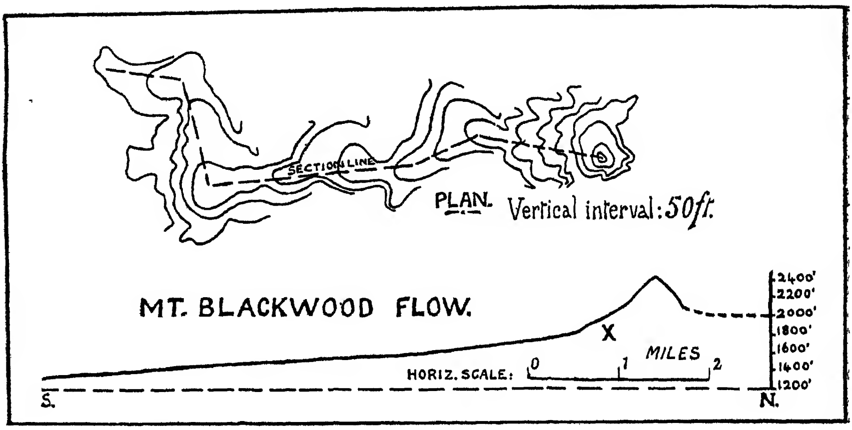


Fig. 21—Contour plan and longitudinal section of the Mt. Blackwood lava flow.

mander of the 'Fly,' 1842-45." Magnificent views are obtainable from the summit of this hill.

(c) *Mt. Bullengarook.*—This volcanic hill also stands on a high base of Ordovician slates, which outcrop on the road that winds round the foot of the hill, at a height of 1900 feet; the total height of the hill is 2207 feet. A contour plan and a section of this hill and the southern lava tongue is shown in Fig. 22. It will be noted that about 4-5 miles from the hill, the flow descends somewhat steeply, and here the Pyrete creek on the east and Goodman's

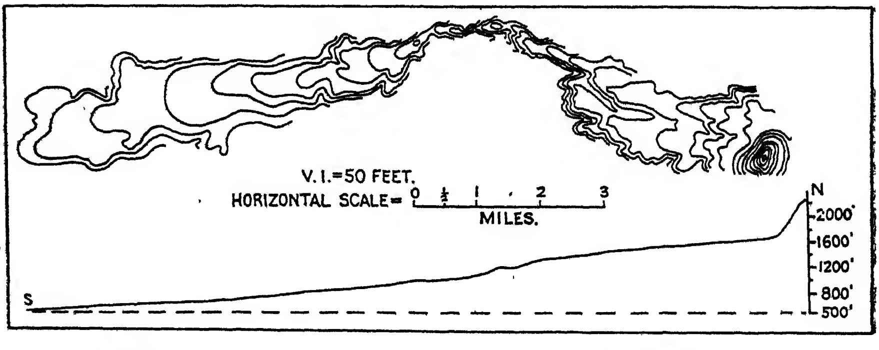


Fig. 22.—Contour plan and longitudinal section of the Mount Bullengarook lava flow The "bight" on the eastern side is largely due to erosion by Pyrete Creek.

creek on the west have carved their valleys back, stripping off the basalt, and in places laying bare the ancient river gravels. A little to the east of Bullengarook is the lower hill (also volcanic) of Little Bullengarook. They stand on the ridge which forms the divide between the Werribee and the Gisborne Creek. An older spelling of the name was Bullancrook.

(d) *Mt. Gisborne and its neighbours.*—Mount Gisborne (2105′ feet). This is a similar volcanic hill, but much more irregular in outline than those already described; it would appear to have produced more extensive lava flows than the hills dealt with above. Although not so high as Bullengarook, Gisborne is the dominating feature of the east-west ridge that forms the divide between the Werribee and Saltwater basins at this place. To the east and south-east, volcanic hills are numerous, and among them may be mentioned Mounts Aitkin (1644 feet), Red Rock (1640 feet), Holden (1360 feet), and Kororoit (779 feet).

(e) *The Anakies.*—Mention has already been made of the Anakies, and little remains to be added here. The volcanic portion of the group comprises three high, treeless, volcanic hills, the most important of which is close against the Rowsley Scarp. Between that hill and the scarp the Anakie Creek has cut its valley, the upper part of which has probably been captured by the Little River. The highest of the volcanic domes is called Mt. Anakie (1350 feet). It is by far the largest single volcanic hill in this area.

(f) *Volcanoes of the Lower Plains.*—Here we have a series of well-known hills. They include Bald Hill (731 feet), Spring Hill (700 feet), Mt. Cotterill (669 feet), Mt. Mary or Green Hill (476 feet), Mt. Atkinson (459 feet), and other lower points of eruption. Mt. Cotterill has a most characteristic shape, and may be easily recognised from a distance on account of its peculiar flat top. Mt. Mary is well known as a breached crater (Gregory, ref. 20), and also possesses interesting geological features very fully described by Kitson (ref. 37). North of Spring Hill, at Nerowie, there are two large natural basins—the northern and larger one being a complete basin, while the one to the south has an outlet; both are cultivated. They undoubtedly represent well-preserved volcanic craters, possibly enlarged by subsidence.

(g) *Volcanoes about Ballan.*—Here again we have a number of hills, whose outlines in most cases are familiar to travellers between Ballarat and Melbourne. The better known ones include Larkin's or Bald Hill (2300 feet), Steiglitz (2090 feet), Gorong (1800 feet),

and Darriwill (1700 feet), while the less known are Ingliston, Hydewell, and "Rae's Hill" The heights given will be noted to much exceed the last-described group of hills, the difference being due, of course, to the positions of these points of eruption on the relatively lifted block of the "Ballarat Plateau."

Larkin's or Bald Hill is a small hill, but owes its greater elevation to the fact that it stands above the Greendale Fault line, just within the timbered country. It is a cinder cone, with the latest breach to the north-west, the lava from this point assisted in forming the newer basalt tongue which flows across the fault line near by. (See Fig. 8.)

Steiglitz is quite treeless and is a low rounded dome with no sign of a crater. Large erupted blocks occur on its summit and slopes, and it has also been the point of origin of a good deal of lava. Gorong is a wooded hill, very scoriaceous, and the northern and western slopes show successive outcropping steps of lava, giving it a peculiar terraced appearance. Darriwill is closely similar to Gorong, and it would not appear that either volcano had ever been greatly effusive. Ingliston is a very small hill, north of the Ingliston railway station. The particular interest of "Rae's Hill," which occurs on "Highton," near Greendale, is its insignificance as a landscape feature. It is an undoubted point of eruption, and yet its elevation above the general level of its flow is only to be noted by close observation. Finally, we come to Mount Hydewell, in many ways one of the most interesting of the group with which we are now dealing. It lies something over a mile south of Ballan, and has a grade so gentle as to be almost imperceptible; yet there seems no doubt that from the point of view of lava production, it is the most important volcano in the district. There is some very vesicular material about the top of the rise, but it would appear to have had very little explosive activity, and hence did not build a cone. This is evidently the point referred to by Mr. Hart (ref. 22), as "an unnamed centre near Ballan," Small streams flow from Mount Hydewell:—

N. and E. to the Werribee River.
E. and S. to the Parwan and Yaloak Creeks.
S. to a swampy area near Mt. Wallace.
W. and S.W. to the Moorabool River.

It probably had a very big destructive effect on the old physiography here and undoubtedly exercised great influence in the location of the present river channels.

(b) *Rivers and Valleys.*

The Werribee River basin as a whole will first be dealt with, in its relations to the neighbouring river basins; then the Werribee in relation to its own tributaries, and finally a detailed description of each river, concluding with an account of the "buried rivers."

(i.) *The Werribee Basin and its Divides.*—The general relations between the Werribee River and neighbouring streams are set out in Fig. 23. On the lower plains we find the Little River and another small stream (Cherrytree creek) adjoining the Werribee on the south, with a very gentle rise acting as divide between them. In the northern part of the plains the relatively high ground around the volcanic centres of Bald Hill and Spring Hill forms a natural divide between the Werribee and the Balliang Creek, a tributary of the Little River. Further seaward this divide is continued in the general rise around Mt. Mary or Green Hill. Thence to the sea the ordinary gentle irregularities of the volcanic plain have determined the limits of the two basins.

The southern tributaries of the Parwan have penetrated very slightly into the Ordovician block of the Brisbane Ranges, having found much easier courses in the soft, level-bedded tertiary sands and clays. Here the fault line bounding the southern edge of the Ballan Sunkland practically forms the divide. The Brisbane Ranges are here drained by headwarter streams of the Little River on the east, and by Eclipse Creek, a tributary of the Moorabool, on the west. The higher ground around Mt. Wallace (volcanic), also helps to form the divide between Eclipse Creek, a tributary of the Moorabool, and Spring Creek, a tributary of the Parwan.

Coming now to the west, the Werribee is bounded in that direction by the basin of the eastern Moorabool. This is a strong, south-flowing river, with a deep young valley cut mainly through the newer volcanic sheet into the Ordovician and other rocks below. The boundary (between the Werribee and the Moorabool, is very low.

Much speculation has been indulged in as to whether the eastern Moorabool originally (in pre-newer volcanic times) flowed into the Werribee, or vice versa, or whether both streams may have been tributaries to a hypothetical ancient Parwan. The area was closely examined for evidences as to this. The point west of Ballan, where the eastern Moorabool takes a sharp loop eastward, so that only a mile of level country separates the two young channels (Moorabool and Werribee) was specially examined. The Werribee here lies

wholly in the basalt, while the eastern Moorabool has cut down through that rock into Ordovician and glacial. There are no sections of old basalt-filled valleys here, as far as the writer could determine, except one close to the Bradshaw's railway station, cut through by the eastern Moorabool. This old stream no doubt flowed to the east, and may be regarded as the ancestor of Paddock Creek.

West of the Eastern Moorabool, and within the easterly loop above referred to, there are comparatively high, rough hills of folded Ordovician slates, with many small patches of glacial sandstones, and flanked on the north by ferruginous tertiary grits. The area was no doubt high land in pre-newer basaltic times, and this fact suggsts the presence of a broad valley extending in width eastward beyond Ballan. This would indicate that the upper streams of the present Eastern Moorabool and Werribee were at that time united in this area.

As we go further north the Ballan to Daylesford road follows the divide between the Moorabool and Werribee basins, as also does an old railway survey. The divide here is still very low and flat, with many swamps; some of these drain to the Eastern Moorabool and some to the Werribee. The rocks are volcanic, capped by sand and buckshot gravels, fairly well timbered. This continues to near Bunding, where the high flat-topped volcanic cone of Egan's Hill separates the two rivers. Further north we descend from the volcanic sheet, and pass to the Ordovician ranges which lie north of the Greendale fault line. The road is here very bad, and the grades much steeper. The Eastern Moorabool (here the site of the Korweinguboora reservoir, Geelong Water Supply) is on the whole in a much more mature valley than is the Werribee. The latter shows that an old lava stream originally filled its course here, but that has now been mainly carved away, and remains only as basaltic patches, underlain by river gravels, somewhat above the present level of the valley bottom.

This country forms part of the State Forest, and is thickly timbered with big eucalypts, blackwoods, scrub, bracken, etc. A lava flow coming down this valley at the present day would have its progress very greatly impeded by this timber, which grows right to the bottom of the valley. The thought arises whether the ancient lava-buried valley was similarly timbered, and if so what became of the trees. Probably very severe "bush fires" would accompany the flows of the molten lava.

Still further north, at the Mineral Spring Hotel, the divide between the Werribee and the Moorabool is an insignificant Ordo-

vician ridge about 50 feet high and a mile or so wide. Immediately to the west, the divide between the eastern and western branches of the Moorabool is much higher, in similar rocks, and three miles wide. It might be expected that, accidents excepted, the divide between any two well-established streams should be more marked than between any two tributaries of one of those streams, when the same rock type prevails. The facts thus suggest that in pre-newer volcanic times the upper Werribee, and the upper Eastern Moorabool were tributaries of the same system, the separation having been effected by Egan's Hill and the lava flows therefrom.

The country rises considerably through the village of Korweinguboora, towards the Main Divide at Leonard's Hill. At Korweinguboora there are two south-sloping, much decomposed tongues of basalt. A shallow valley on one of these tongues leads to the Werribee, while a similar tributary gully of the Eastern Moorabool runs along the western side of the same flow. The country thence rises to Leonard's Hill. This point is on the Divide, and has already been described.

Thence eastward, the Main Divide of Victoria separates the Werribee on the south from the Loddon and Campaspe Rivers on the north, as detailed in a previous section. On the whole, the Divide here is migrating northward. No captures from the northern rivers are to be noted, and the advance northward by the head waters of the Werribee and the Lerderderg is more in the nature of a general "nibbling" along the whole front, rather than a sudden acquirement of large territories by captures.

From the Main Divide, south-east about seven miles to Mount Bullengarook, the divide separating the Werribee basin from that of the Gisborne Creek (a tributary of the Saltwater), is in thickly-timbered Ordovician country. Enquiries from saw-millers who had been through that part elicited the fact that a rough bush track runs along this divide from Bullengarook to East Trentham. This was not examined, but the steep ravines that were seen to mark the headwaters of the Goodman's Creek and the Lerderderg, when compared with the wide valley of Gisborne Creek, point again to the more vigorous work being done in the basin of the Werribee.

From Mt. Bullengarook the divide is irregular, running generally eastward through Mt. Gisborne. It is partly a high, well-dissected Ordovician block, largely covered by basaltic hills and flows. The gully heads of the Pyrete or Coimadai Creek, the

Djerriwarrh or Deep Creek, and (to a less extent) the Toolam Toolern Creek, are deeper and steeper-sided than those flowing northward from this divide.

While the three creeks just referred to flow southward to the Werribee, there is a fourth parallel stream going southward—the Kororoit Creek—which turns east on reaching the low basalt plains, and enters the Bay independently. This course was evidently selected owing to minor irregularities in the surface of the volcanic plains. To follow the divide between the Werribee and the Kororoit Creek basin, we must now descend from the Gisborne highlands, and travel southward.

The western branch of the Kororoit Creek, in the higher levels, is very closely related to the eastern branch of the Toolern Creek, and minor captures appear to have taken place. On the plains, from near Melton down to the sea, the divide is low, with few and small irregularities similar to that between the Werribee and the Little River already described. Between Kororoit Creek and the Werribee a small valley (the Skeleton Water Holes) comes from the slightly higher country about Mts. Cotterill and Atkinson, and helps to drain the plains, flowing directly into the sea.

(ii.) *The Werribee River in relation to its own tributaries.*

The complex nature of the Werribee and its tributaries will be seen from a reference to the special river map (Plate XIIA.), and the grade profiles of the Werribee (Plate XIIB). It may be here explained that the plan of the Werribee and its tributaries has certain imperfections; it is based on the county plans of Bourke and Grant, and where the streams were unmarked in those maps, an effort was made to complete the map from other sources. The

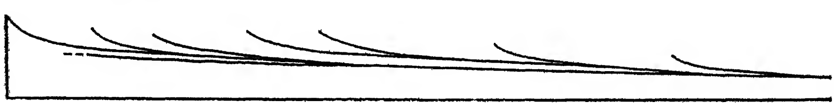
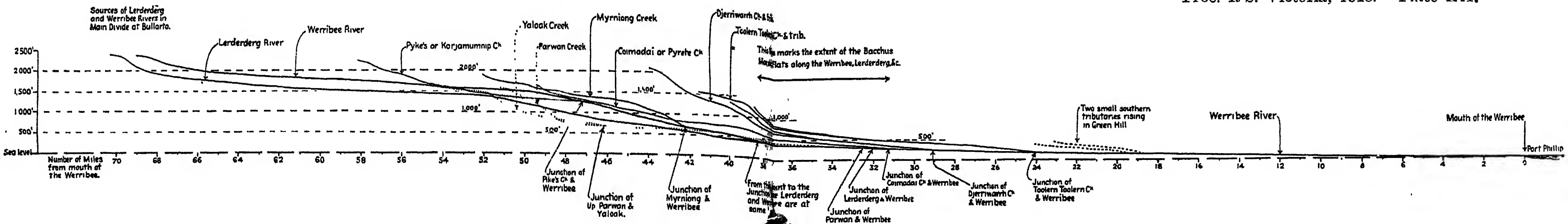


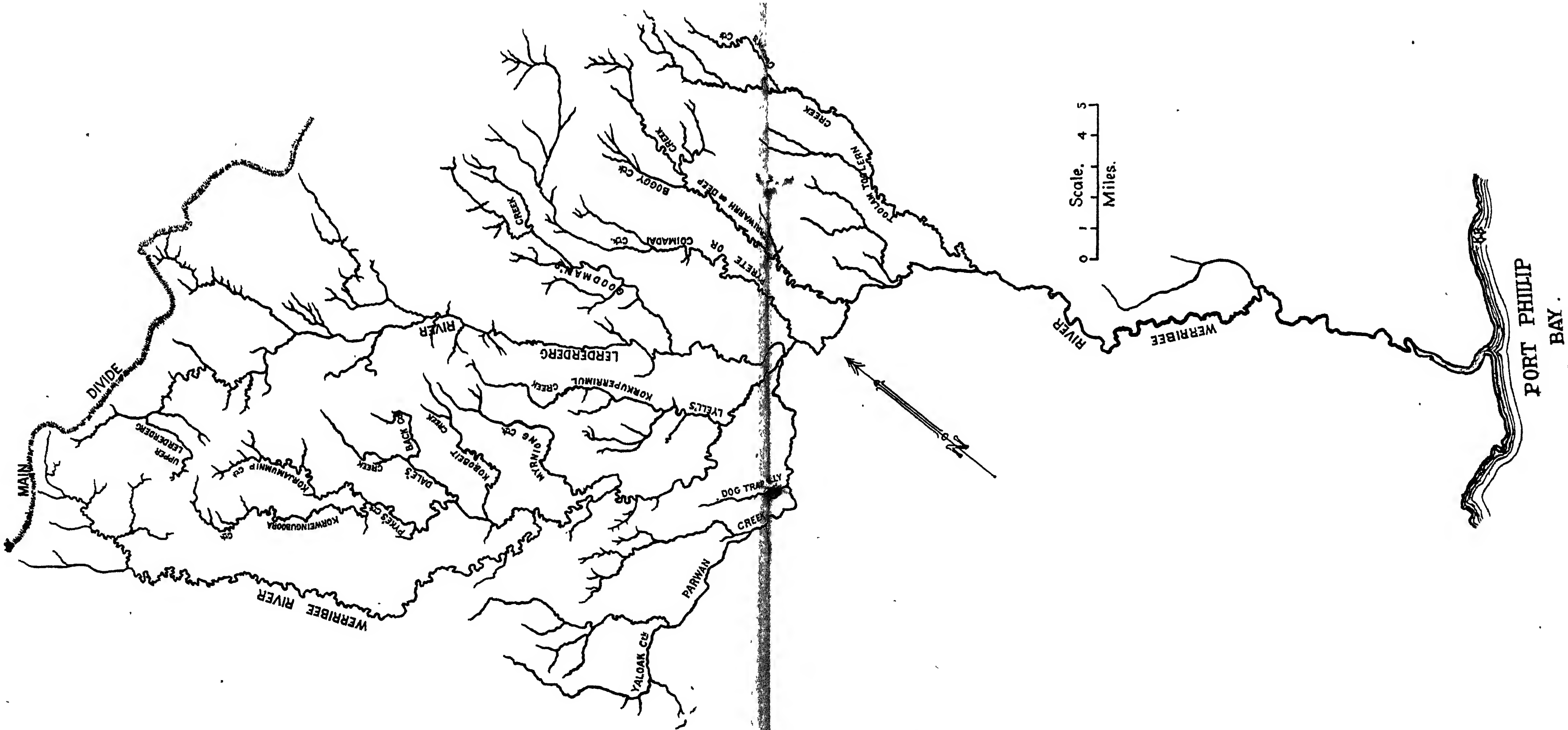
Fig. 23—Characteristic longitudinal section, showing relative grades of a stream and its tributaries, after Nussbaum (ref. 32).

general plan of the main streams is quite correct, but exactness is lacking in the tributaries of Goodman's Creek, the upper Pyrete, and the Lerderderg.

It may also be explained that the grades of the rivers and creeks were plotted from levels supplied by the published maps and field notes of the Military Survey, supplemented in the unmapped parts



B Profile sections, to scale, of the valley bottoms of the Werribee River and its chief tributaries.



A General plan of the Werribee River and its tributaries.

by aneroid records taken by the writer. The idea of plotting the grades thus was suggested by a similar piece of work by Nussbaum (ref. 32), Nussbaum's diagram has been carefully re-plotted on a larger scale, and turned in the opposite direction (Fig. 23), to afford easier comparison with the profiles of the Werribee River and tributaries (Plate XIIB.).

The great variety of river types in the Werribee area is due to four outstanding facts. The first of these is the variety of the rock types, which has already been referred to, and the other three include the two important periods of differential uplift, and the great newer volcanic period. Each factor has left its impress on the present river system.

Before proceeding to discuss these factors, the question arises: Which is the dominant stream, the "name-stream," of any river? The matter is important from the physiographic and cartographic standpoints. A physiographer, regarding a map of any river, may conceive it as lopsided, receiving most of its trubutaries from one side only, when perhaps the fact may be that a minor or tributary stream has been given the "name-dominance," by an error of judgment. Similarly cartographers doing small scale maps only include the main stream, according to the name thereof, and if that has been badly selected, the map does not truly represent the facts.

The writer conceives this to be the case in the Werribee area. It may be shown that from the point of view of depth, age, length and volume the Lerderderg is the most important branch of the Werribee System. Economically, however, early settlement of the area trended more along the present day upper Werribee. In 1845-6, when Hoddle, Darke and Urquhart surveyed the Werribee, etc., as part of the boundary of the country of Bourke, this was therefore the stream surveyed. (See original plans, Lands Department, Melbourne.)

Reference to Figure 23 will show that Nussbaum's "characteristic longitudinal sections" place the main stream always at the lower grade, and, as explained by Hobbs (ref. 32) in the context: "Lateral streams, from the fact that they are tributaries, likewise descend upon somewhat steeper grades." If now we refer to the actual grades of the Werribee and its tributaries, we find a complex of apparent anomalies—each of which may be explained. (Plate XIIB). The point that might be stressed here, however, is that the "main or trunk stream"—the Upper Werribee—is everywhere at a higher level than the Lerderderg, and may be truthfully said to "flow into" the latter. It would seem that the commonsense

way of really deciding a "trunk stream" would be to follow up the river from the mouth, and at each junction to select the stronger of the joining streams.

Speaking now of the Werribee as it is mapped and accepted, we shall consider its relations to the main tributaries. The Werribee flows south-easterly, receiving all its main tributaries from the north, with the single exception of the Parwan Creek (Plate XIIA., For the purpose of a clear understanding, these tributaries may be set out as under :—

- Werribee
  - Northern Tributaries
    - Pyke's
      - Korjamumnip
      - Korweinguboora
      - Dale's . . . Back
      - Korobeit
    - Myrniong
    - Korkuperrimul
    - Lerderderg
      - Goodman's
      - Clearwater
      - Sargonne
      - Allen's
      - Split Tree, etc.
    - Pyrete
    - Djerriwarrh
      - Boggy
    - Toolam Toolern
      - Condon's
  - Southern Tributaries
    - Parwan
      - Yaloak

The general directions of these tributaries are clearly set out on Plate XIIA., and need no further description. The interesting point of relationship is to be seen in their relative grades. Only the chief tributaries are plotted in Plate XIIB., since the addition of lesser ones would only add further complexity, without giving any additional information. It is at once apparent that the grades of the Werribee system, and their relationships depart very much from the "characteristic section" drawn in Fig. 23.

As already stated, the Lerderderg grade-line lies everywhere lower than the Werribee, except that for the last three miles before they junction, the grades are practically the same. This is in the Bacchus Marsh flats. The reason for the Lerderderg's lower levels are the greater age and the greater volume of that stream; it has been practically uninfluenced by the newer volcanic flows, and is for the greater part in the most elevated and most difficultly eroded block of land in the area.

While the Parwan is seen to grade into the Werribee in quite a normal way at the junction, its line crosses that of the latter about three and three-quarter miles up stream, and thence lies at a much lower level (500 feet lower in places), except where its

extreme head waters grade rapidly up to the basalt plains. This is due to the fact that the course of the Parwan above the scarp is in extremely soft, level-bedded, tertiary sands, etc., with a thin basalt covering, while the Werribee was in hard, folded Ordovician, etc., also partly covered by a basaltic sheet. (See Fig. 24.)

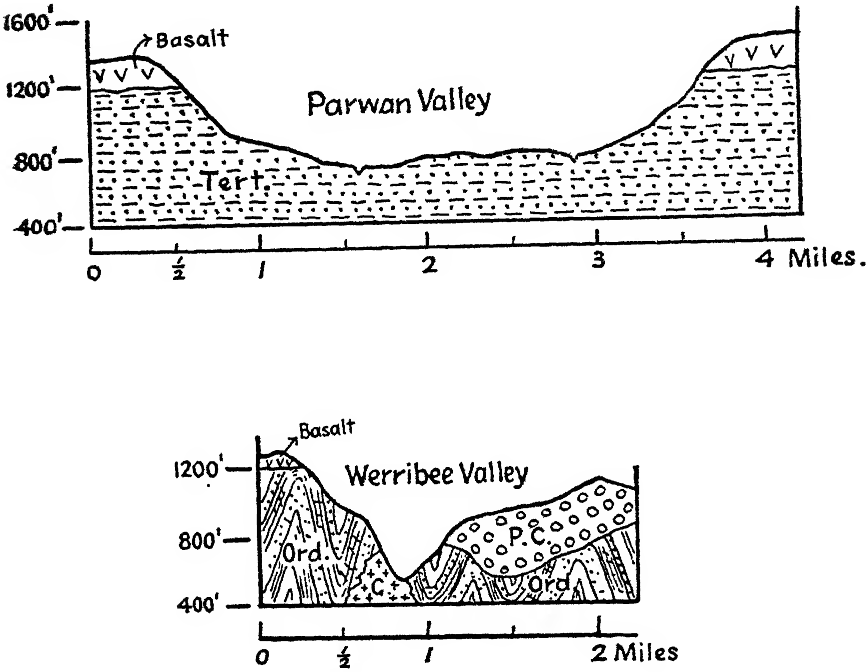


Fig. 24.—Sections across the valleys of the Parwan and Werribee valleys, at approximately equal distances above the scarp. To show the extent of the work of the Parwan in soft, level-bedded Tertiary sands and clays, compared to that done during the same period by the Werribee in the more resistant Ordovician, granite, and Permo-Carboniferous rocks.

It will be noted that Pyke's Creek, while it flows for a couple of miles at levels higher than those of the parallel Werribee, rapidly deepens, and for nearly four miles is much lower than the latter, entering at a gentler grade than that of the parent stream. The explanation is probably to be found in the fact that Pyke's Creek, with its many tributaries, has a larger catchment area than has the Werribee from their junction upwards. Pyke's Creek basin also lies for a good part of its course in more easily-eroded rocks—sandstones, decomposed older volcanics, and tuffs. It is no doubt

from a consideration of the above facts that the site for a storage reservoir in this area was selected on Pyke's Creek. From a consideration of Plate XIIB. we can also see how it has been possible for a tunnel to be dug, almost normal to the course of the Werribee, to lead its waters through the intervening higher area, into the Pyke's Creek Reservoir. When we come to consider the grades of the streams as a whole, we find remarkably fine evidence of the uplift and rejuvenation which have already been shown to have markedly affected the topography of the Werribee area. For purposes of comparison the profile of a rejuvenated stream (Lockajong River, N.J., U.S.A.), has been re-drawn from ref. 10 to the same scale as used for the Werribee (see Fig. 25). We see in this Locka-

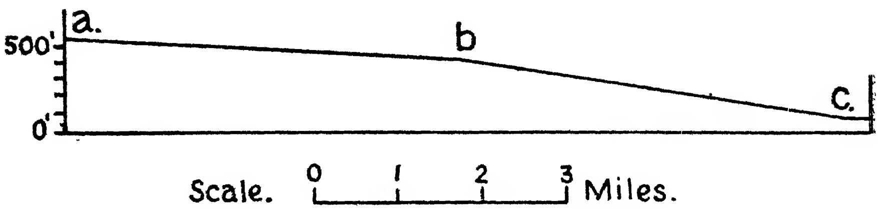


Fig. 25.—Profile of a rejuvenated stream. Lockajong River, N.J., U.S.A. (from Chamberlain and Salisbury) for comparison with the profiles shown in Plate XIIB.

jong river gradient that the characteristics of rejuvenation are shown by a gentle grade, a-b, a steeper grade, b-c (with gorges), and then once more a flatter grade from c onward.

This type of curve is strikingly shown in every river on Plate XIIA, with certain variations, which would naturally be expected, and which will be dealt with. In the lower reaches of the river a few small streams have been plotted. These flow over the volcanic plain, and then descend somewhat sharply into the steep gorge cut by the Werribee through those plains.

(iii.) *Details of the Individual Streams.*

(a) The Werribee.—This river is about 71 miles long. Its source lies on the Main Divide, near Mossop's Hill, Old Bullarto, and has been described. The course here lies in Ordovician rocks, and rapidly deepens. It is here mainly occupying an old valley that had been partly filled by a volcanic flow, but of which only remnants now remain. The gravels below these patches of basalt have been worked for alluvial gold. Musk Creek and Spargo Creek enter the river in steep-sided gullies from the east.

For the first six miles the Werribee flows south, parallel to the Eastern Moorabool. Just below the Greendale fault line it flows on to newer basalt, and thus continues past Ballan; the valley here is shallow and insignificant. It turns easterly at Ballan, and thence flows in a young V-shaped valley about 150 feet deep, cut into the volcanic plain. Between Ballan and its junction with Pyke's Creek, the bed exposes a variety of rocks such as might be expected hereabouts only in the Ballan sunkland: small patches of Ordovician sandstones, permo-carboniferous glacials, buried river gravels, etc. In several places it bisects deeper portions of the basalt, of which a better knowledge may some day give material for the mapping of the pre-basaltic river-beds there.

Where the river passes at the foot of Mt. Darriwill, a tunnel has been made to lead water through to the adjoining valley into the storage reservoir of Pyke's Creek. Half a mile or more before the Werribee joins Pyke's Creek, it has almost cut through a tongue of thicker basalt, giving a fine exposure of a pre-basaltic valley, cut in the underlying granodiorites. The present river course here is tortuous, probably due to meanders inherited from its original channel in the basalt plain, and exaggerated as the river deepened.

From Pyke's Creek downward, the grade is much steeper, cutting through the granodiorites and Ordovician beds on which it has been superimposed. These hard rocks have caused the river to give all its attention to downward erosion, and we pass into a precipitous gorge. For the next three miles, to the eastern end of "the Island," this gorge grows deeper, and here the steep-graded Myrniong Creek enters on the northern side.

From this point onward for about two and a-half miles, the river turns and twists through a gorge of great scenic beauty. The land on the left bank of this area, adjoining the river, has been proclaimed a public park. An excellent section showing the structure here has been prepared by Mr. C. C. Brittlebank, and published in the Monthly Progress Report of the Victorian Mines Department, May, 1899. Steep cliffs nearly 800 feet high occur, showing fine exposures of the great anticlines and synclines of the Ordovician, the junction of the latter with the granodiorite, old glacial valleys and striated "pavements," and many other features which combine to make this gorge an area greatly favoured by Victorian geologists. It has been described as "scientifically, the most famous place in Victoria."

On the south, a deep tributary comes in from the patch of bed-rock here exposed at the surface. This tributary, with its steep and densely timbered slopes, also provides some fine scenery, especially by contrast with the flat, uninteresting plains above. When the river emerges from the Ordovician, we come to the "mouth" of the Gorge, and in the softer rocks hereabout—mainly tertiary and decomposed older volcanics—the valley is wider and the land of greater economic value. A view near this point is shown in Fig. 26. The gentler slopes are lightly timbered, and rich river flats make their appearance. Past the residual basalt-capped Trig Hill, the Korkuperrimul Creek enters in a wide valley from the north, at a grade quite harmonious with that of the parent stream.

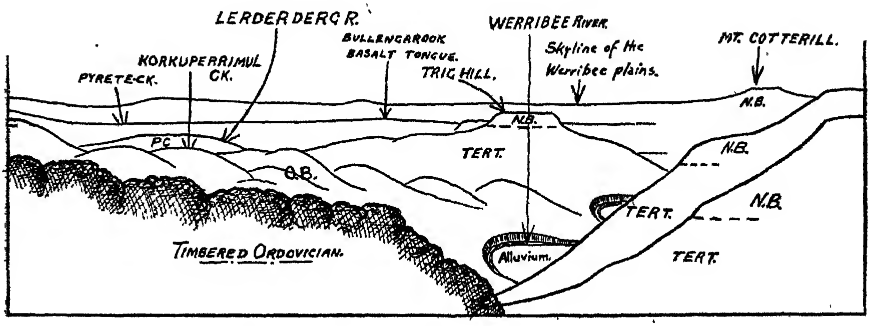


Fig. 26.—Sketch, looking east, of the view from the hills on the right bank of the Werribee River, below the Gorge. N.B.—Newer Basalts; Tert.—Tertiary sandstones, etc.; O.B.—Older Basalts; P.C.—Permo Carboniferous sandstones, etc.

We here pass the line of the Rowsley fault, and a small let-down tongue of lava crosses the river coming from Bald Hill. This causes a narrowing of the valley (see Fig. 38). Beyond that the river valley widens out into the fertile flats of the Bachus Marsh basin, through the alluvial of which it runs in a channel 10-20 feet deep. As is usual with such flood plain deposits, the levels of the "flats" slope away from the river for some little distance.

The structure and origin of this basin is discussed later. Towards the further end of this area, the Parwan enters from the south, and the Lerderderg River from the north, with the Pyrete Creek coming in from the north a quarter of a mile further on. The Werribee then leaves the flats, and swerves to the south, entering once more a young, narrow valley cut into the basalts (see Fig. 38). From this point onward the river flows generally south-east, across the plains, to the sea. A little over two miles along

this narrow gorge the Djerriwarrh enters from the north, at a low accordant grade.

A mile and a-half further, the Melbourne-Ballarat railway crosses the Werribee, at a point where a small unnamed tributary valley

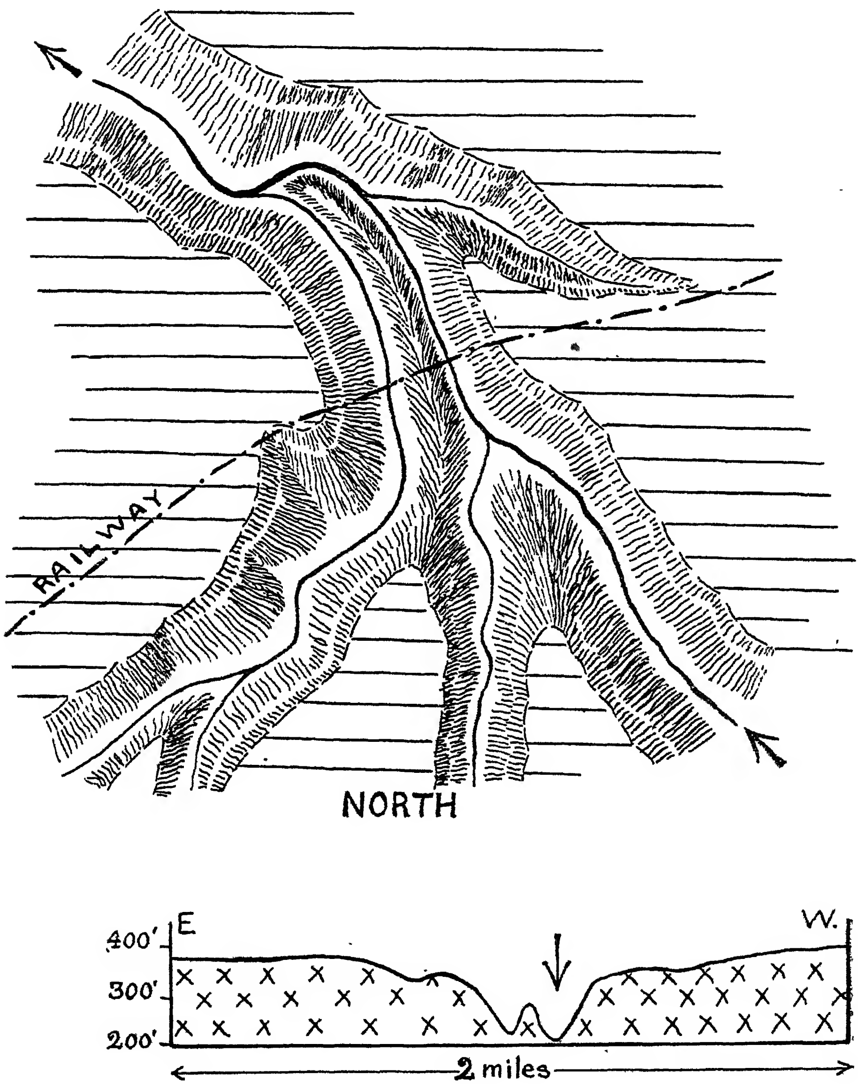


Fig. 27.—Junction of small stream with the Werribee River in the basalt plains near Melton. The Werribee is indicated by arrows. This shows also typical plan and section of the narrow valley of the Werribee in these plains.

enters from the north. This junction presents features of some interest, and has often been remarked by travellers with an eye for topographical features. Both the Werribee and the small tributary valley are in basalt, but the tributary delays its entrance in a peculiar way, running parallel to the main stream for some little distance. A plan and section of the junction is shown in Fig. 27. The bed of the Werribee is here 160 feet below the general surface level of the basalt plain. This feature has been erroneously referred to (Vic. Handbook, B.A.A.S., 1914), as a "deserted creek bed."

An iron viaduct, 1130 feet long, here spans the Werribee, the foundations for this structure penetrate deeply into "alternating beds of sand, gravel, clay, and lignite," which underlie the basalt. For the greater part of the year, the waters of the new storage reservoir at Exford now submerge the feature described in this paragraph.

Three miles further down stream, at Exford, the Toolern Creek enters from the north, at an accordant grade. The erosion about this junction has given gentler slopes to the sides of the valley, and three roads meet here to cross the river. Immediately above the junction is the site of the Exford reservoir; from the nature of the valley the stored water will be contained in a very long and narrow dam, reaching upstream for several miles. For the remainder of its course (twenty-four miles) the river receives no tributaries, flowing evenly along in a young valley averaging 150 feet in depth. At the town of Werribee, where the Geelong-Melbourne road and railway cross the river, it enters a triangular area of river gravels and dark-coloured alluvium, though which it cuts its channel to the sea. The appearance of the mouth was roughly compared with a survey of fifty-five years ago; it is very slightly different at the present day. (See Quarter Sheet 20, S.E.) Just as we found rich farms at the very source of the stream, seventy-one miles away, and 2400 feet higher, on the top of the Main Divide, so here at the mouth the land is irrigated and cultivated to the very edge of Port Phillip Bay.

(b) *The Lerderderg River.*—The source of this river in the Main Divide has already been described. It is close to, and at the same level as, the source of the Werribee, separated therefrom by a low ridge. Erosion in the cultivated land of its extreme upper reaches is rapid, and the loose chocolate soil is being fast carried away. Springs from beneath the basalt provide excellent water, and are permanent. The Lerderderg valley deepens rapidly, and

as one stands at the source and looks down stream, the river is seen to pass into a wide, deep, thickly-timbered, uninhabited valley carved out in the Ordovician rocks of the uplifted peneplain. As before stated, the Lerderderg, down to the point where it crosses the Rowsley Fault, is an old river rejuvenated; one may detect a valley-in-valley structure at various points, and there seems no doubt that this river was one of those that in early to middle tertiary times completed an erosion cycle by the formation of the peneplain. The Lerderderg here receives tributaries from the south and north, and the valley appears quite basin-like, narrowing in as it rounds the southern side of Mt. Wilson—an important residual range. The river then flows east and south-east through the mining township of Blackwood. Terraces of auriferous allu-

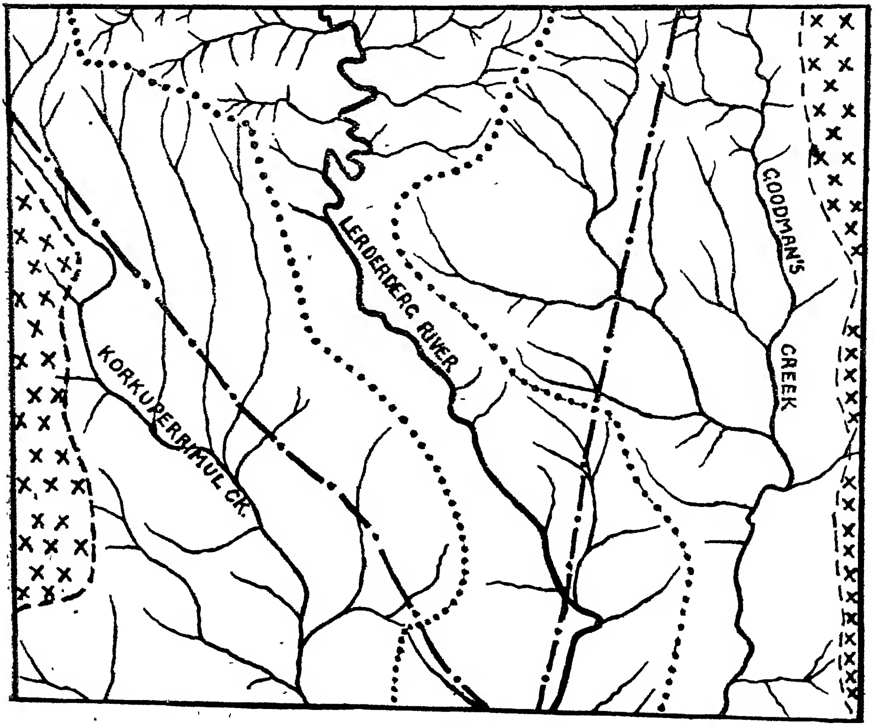


Fig. 28.—Plan showing probable captures from the Lerderderg River. The thick, broken lines represent prominent Fault Scarps. Tributaries of the Korkuperrimul and Goodman's Creeks, working back from these scarps, have entirely robbed the Lerderderg here. Within the triangle formed by the fault scarps, the rocks are hard ordovician slates, through which the Lerderderg flows. The part marked with crosses represents basaltic flows.

vial remain in places along the valley sides, at varying distances above the present bed. At Blackwood, the river cuts right across the strike of the almost vertical beds, exposing anticlines and synclines. It is believed by Blackwood miners that the course of the river is here directed by a large east-west dyke. As the river trends south-easterly through the ranges, with many loops and meanders, its valley is over 800 feet deep, with precipices 500 feet sheer in places. From the summit of Mt. Blackwood its valley may be traced through the Ranges, completely bisecting the uplifted peneplain; beyond, we may see where it opens out on to the flat country below the Rowsley Fault scarp.

The last few miles of the Lerderderg gorge are reproduced in plan in Fig. 28, showing how the neighbouring creeks have robbed the Lerderderg of its territory. One may note here the extreme narrowness of the area drained by the Lerderderg; the sketch shows the positions of the Korkuperrimul and Goodman's Creeks, both of which, working largely in soft glacial sandstones, appear to have enlarged their basins at the expense of the Lerderderg.

Immediately the fault line is crossed, the river passes from a young stage, with a valley 1000 feet in depth, to the stage of an old river meandering across a flood plain, and with numerous terraces. At the northern end of the Lerderderg flats, near Kerr's farm, a pretty series of terraces occurs, as reproduced in Fig. 29, from a notebook sketch. The "meander belt" here is bounded by two cliffs of hard glacial conglomerate C_1 and C_2. Compared with an ideal terrace series it will be seen that a peculiar restriction occurs; while normal down-stream "sweeping" is observable in terraces 1, 2, and 3 on left bank, this has been restricted on the right bank by a hard cliff of glacial material at X. This section at X is also instructive insofar as it exposes evidence of a now buried terrace series, cut into the old glacial beds. These terraces are worthy of a more detailed study than the writer was able to give.

Just above this point, the interesting tributary of Robertson's Creek enters the Lerderderg. It has a very steep grade, and has built up a fan delta where it enters the larger valley. Its course lies mainly along a fault junction—the eastern end of the Greendale fault. It is vigorously cutting into the older basalts, glacials, etc., of its right bank; the left bank is Ordovician. It appears to be about to capture the head valleys of a small Korkuperrimul tributary; and apparently even now receives some water from that stream during heavy rains.

As the Lerderderg flows on through the "flats," it is bounded, at some distance, on the right bank by the treeless, residual ridge of Bald Hill (glacial and older basalts) and on the left bank by the sands and clays of the tertiaries, overlain by the tongue of newer

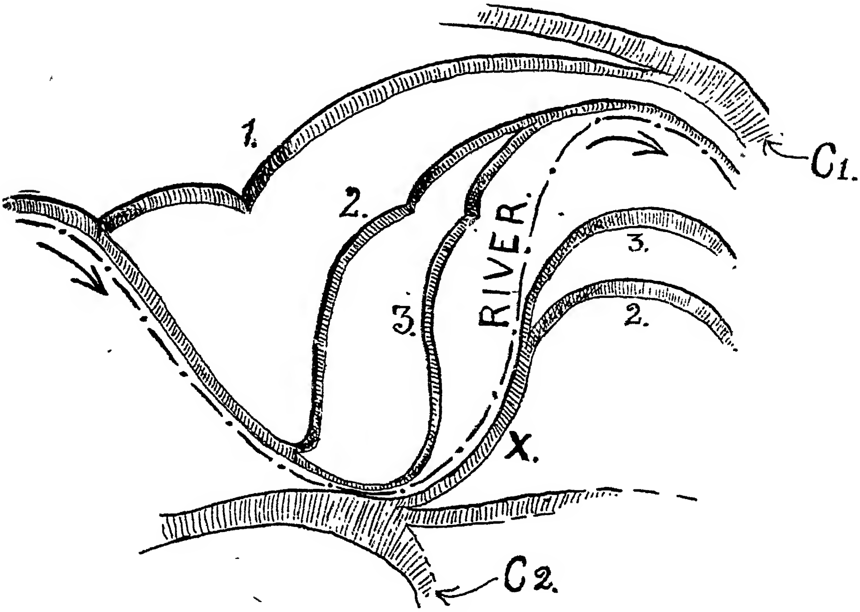


Fig. 29.—Plan of terraces on the Lerderderg River, near Kerr's farm, above Darley.

basalt that filled the "Ancient Bullengarook" Creek. Ordovician is exposed in the bed of the creek at the Darley Bridge. An important tributary, Goodman's Creek, coming from the north, enters about a mile above this bridge. While this part of the river is referred to above as "older" than the upper Lerderderg, it is of course only so in form. As a matter of fact this mature valley, in soft rocks, is post newer basaltic in age, and from the point of view of time, much later in origin than the portion of the valley in the ranges. From Robertson's Creek, right down to the town of Bacchus Marsh, the western side of the valley, between the present bed and the Bald Hills, is covered by thick terraced deposits of coarse pebbly alluvial, standing at high levels. For the last mile of its course, the river runs parallel with the Werribee, in a similar channel, in deep alluvium, and joins that stream near the eastern end of the Bacchus Marsh basin.

(c) *The Parwan and Yaloak Creeks.*—The Parwan, with its tributary Yaloak, is the only tributary of any note to the south of the Werribee. Its upper valley is very impressive, especially when

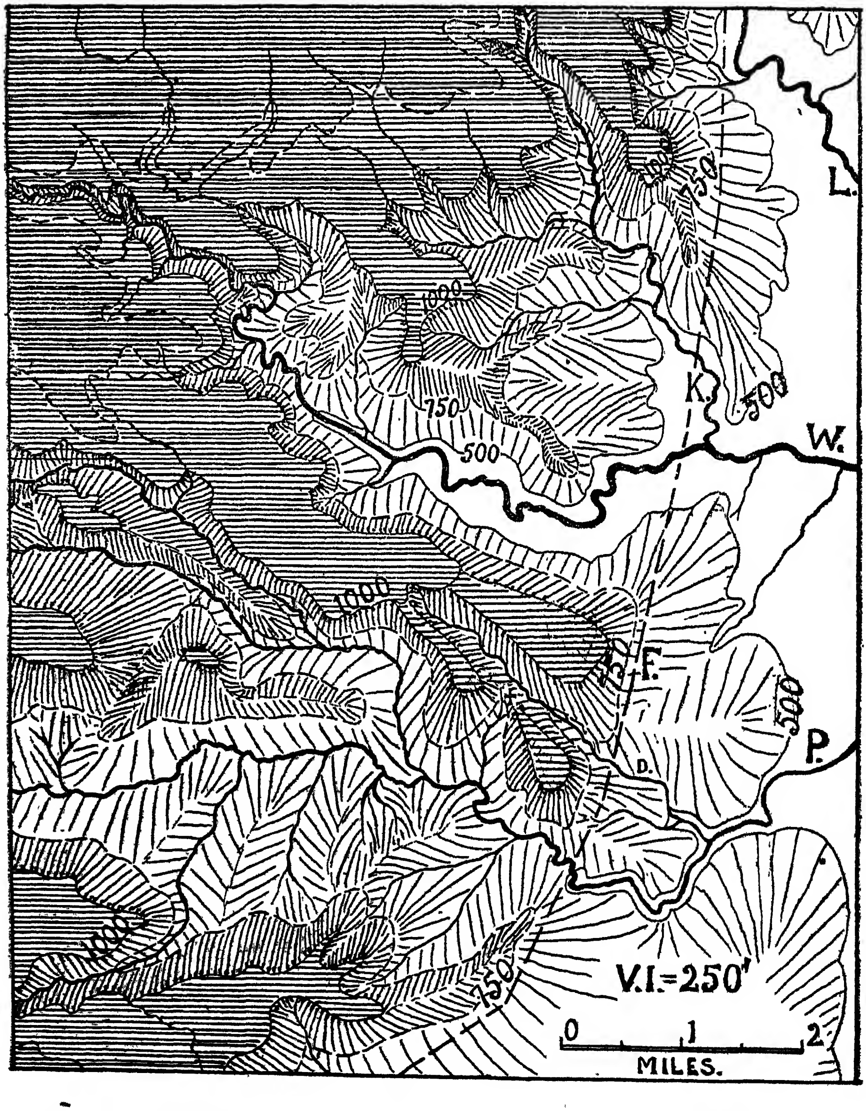


Fig. 30.—Differential erosion of the Rowsley Scarp at Bacchus Marsh, 250-foot contour intervals. The original line of the scarp is marked F. L.—Lerderderg; W—Werribee; P—Parwan; K—Korkuperrimul. This is the most deeply eroded portion of the scarp.

we consider the size of the creek which carved it out. It is a great irregular basin, four miles across, about eight miles in length, and 800 feet deep, descending sharply from the surrounding newer volcanic plains. Except for the last five or six miles from the edge of the scarp to the Werribee, the Parwan lies wholly in this basin. It is a small stream at best, and is dry for a large part of the year. The amount of arosive work accomplished is therefore all the more astounding, and is indicated to some extent in plan (Fig. 30), and in section (Fig. 24).

This plan (Fig. 30) is drawn to indicate the amount and nature of dissection of the fault scarp in the neighbourhood of Bacchus Marsh. It also indicates the differential erosion due to differences of rock structure, and this is again shown in the two sections chosen (Fig. 24). The smaller stream (Parwan Creek) has carved a valley of the dimensions indicated, while the much more powerful Werribee has carved out the well-known "Gorge." Both streams are here exactly the same age; but while the Werribee worked, as already indicated, in very resistant rocks, cutting mainly across the strike of hard Ordivician sediments, the Parwan had the advantage of a location in level-bedded, uncompacted tertiary materials; in both cases there was a covering sheet of newer volcanic. Landslips play a great part in the enlargement of the Parwan basin, and their influence is seen in the steep, broken, lumpy, white-streaked, unstable valley slopes. Residual ridges and hills occur within the valley, some of them capped with basalt which stands at a lower level than that of the plain. Such

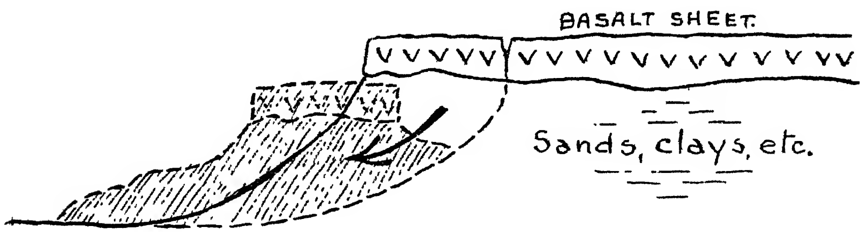


Fig. 31.—Diagram to indicate the possible mode of formation of certain hills in the Parwan valley.

cases possibly represent land-slipping on a large scale. A large mass of basalt, with the thick underlying tertiaries rendered unstable by a thorough soaking during an extra-wet season, has "slumped" boldly into the valley, as suggested by the shaded portion in Fig. 31. The head waters of the Parwan and Yaloak Creeks

are still vigorously cutting back, as shown in Fig. 37. Spring Creek, a southern tributary, flows partly along the junction between the tertiaries and the Ordovician; it has a deep narrow valley, already referred to.

Just within the basin a valley enters from the north, and was carefully examined on account of the possibility of a small capture. The locality is shown in plan in Fig. 30. It will be seen that the last left bank tributary of the Parwan has cut back to the Dog Trap Gully, and only a ridge of soft, white clay separates the two streams. Very little perceptible change has taken place in the past fifty years. In the lower part of the stream some small ravines are cutting back. Capture will no doubt take place at this point in time, since the Parwan tributary has a steeper grade and has no basalt to impede its downward cutting. The Dog Trap Gully is flowing along the side of an old basalt-filled river, and in places basalt still occurs in its bed. An interesting relic of earlier days was found on the ridge at the head of this tributary, where hundreds of chipped flakes of flint, chert, quartzite, etc., testified to an old aboriginal camping place.

An observer standing at the bridge some little distance within the wide Parwan basin, would have difficulty in discovering the outlet of the Parwan, as the basin appears to be completely surrounded by hills. On the right bank of this creek an interesting hill occurs (ref. 56, note 16). This is represented in Fig. 32. The

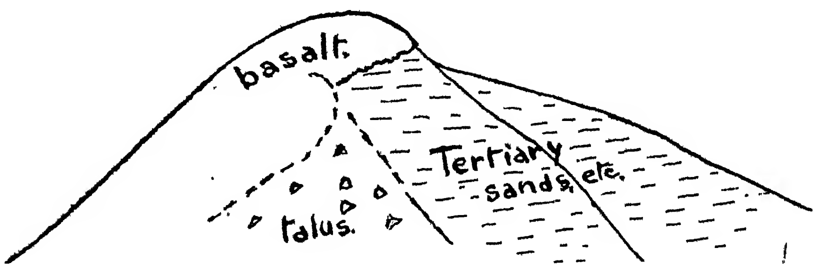


Fig. 32.—Sketch of ridge at the right of the point where the Parwan Creek crosses the line of the Rowsley Fault.

basalt in places is ropy in structnre, and the evidence here taken alone would perhaps suggest that the lava had flowed over a low scarp. This is, however, negatived by other observations, as already pointed out in section VIII. (b).

Just before leaving this basin the river meanders a good deal through irrigable flats, and then passes out through a narrow gut

in the basalt, thus leaving the scarp. Thence to the Werribee, the Parwan flows north-east across the basalt sheet, which it has cut through in its lower part, exposing the tertiary beds below. The last couple of miles are across river flats, and the Parwan then enters the Werribee not far from the junction of the latter with the Lerderderg.

(d) *Pyke's Creek.*—This creek is marked in most maps as the Korjamumnip, but locally it is called Pyke's Creek in the lower part, after one of the early settlers. It has as tributaries the Korjamumnip, Korweinguboora, Dale's, and Korobeit Creeks—all of which have their origin in the high block north of the Greendale fault, along an easterly ridge that runs from near Blakeville to Mt. Blackwood (see Fig. 18). Their valleys probably originated subsequently to the Greendale uplift, due to the cutting back of small streams into the scarp face. As they proceeded thus they probably occupied some of the southern territory of the ancient Lerderderg, The influence of the rock structure of the Ordovician beds is shown in all these streams, but more clearly in the case of the Back Creek, which will be considered later.

The Korweinguboora Creek rises near Blakeville, and does not now occupy its original valley, which was basalt filled during the newer volcanic period. Just before leaving the ranges, it occupies a deep gorge between this newer basalt tongue and the Ordovician. (Fig. 8.) On emerging from the ranges the river turns eastward along the line of the Greendale fault for about a mile, with a high steep scarp of Ordovician on the left bank, and thick, but much lower, deposits of older basalt on the right. It then turns south into the older basalt, in a gently rounded valley, almost treeless, but well grassed, and a mile from the scarp it joins the Korjamumnip.

Tht Korjamumnip Creek flows southward from its origin in the ridge mentioned, in a steep, timbered valley. Among its numerous tributaries in the ranges is the Green Hills Creek, a small stream rejuvenated by a basalt flow. Steep valleys continue to the edge of the scarp, where, like the Korweinguboora, this stream also turns eastward along the fault line, and then south through the older basalts. The distinct nature of the valleys of all these streams after crossing the Greendale fault is very marked. Above the fault the valleys are over 500 feet deep, narrow, and V-shaped; immediately below they are at most 150 feet deep, wide and U-shaped. There is also the important differences of rocks and soils above and below the fault, already pointed out in other

sections. The Korjamumnip flows south through older basalts and glacial sandstones as far as the Ballan-Greendale road, when a marked change is noted. The influence of the newer volcanic sheet is apparent, and the valley is much deeper and narrower. It is here known as Doctor's Creek. Landslips are very common along the steep slopes, in the decomposed and "greasy" older basaltic material that underlies the newer basalt. Beyond "Highton" the creek turns east, and receives Dale's Creek coming in a similar valley from the north. A mile and a half further the Korobelt Creek comes in from the east, and here the Pyke's Creek reservoir has been built, where the Melbourne-Ballarat road crosses the valley.

Thence onward the Pyke's Creek has a deep gorge cut into soft tertiaries, hard glacials, and still harder granites and Ordovician, to the junction with the Werribee. As shown in the profile diagram (Plate XIIA.), the lower part of Pyke's Creek is much deeper than the parent Werribee, the possible reasons for which have already been advanced.

Dale's Creek flows south from near Green Hills, in the northern ranges. Near its head the valley is wide and shallow, but rapidly deepens. Just before reaching the scarp, it suddenly turns eastward, leaving thick deposits of coarse fan delta material piled up near the face of the scarp (eastern part of Garibaldi Hill). This easterly turn may possibly be ascribed to capture by another small stream that had cut back from the scarp face and got into the soft material of an E.-W. dyke, such as are known to abound in the area. Where Dale's Creek now crosses the fault line, it passes into glacial sandstones, and the contrast in the appearances of the valley above and below the fault is even more marked than in the cases already mentioned. A wide dyke marks the creek-bed juncton between the Ordovician and glacials. Thence to "Glenpedder," the valley is wholly in glacial sandstones, with small flats, and bounded by the rounded, grassy hills which mark the village of Greendale. Opposite "Glenpedder" homestead a high cliff occurs in the glacial conglomerates; below, as far as the junction with Pyke's Creek, the valley is in older basalt, with gently sloping sides.

Back Creek is mostly in the ranges, since it joins Dale's Creek less than a mile below the Greendale scarp. Messrs. P. B. Nye and B. Liston, who surveyed this small stream, were continually struck by the prevalence of almost right-angled junctions between N.-S. and E.-W. valleys. The strike of the rocks is almost due

N.-S., and E.-W. dykes are numerous, some having been located at the points where E.-W. valleys join the main stream. It is natural to infer that the structure of the rocks has very greatly influenced this creek, especially as regards its N.-S. and E.-W. valleys. It would appear from Fig. 33 that a second series of fractures has also influenced the stream, running about east 47°N.;

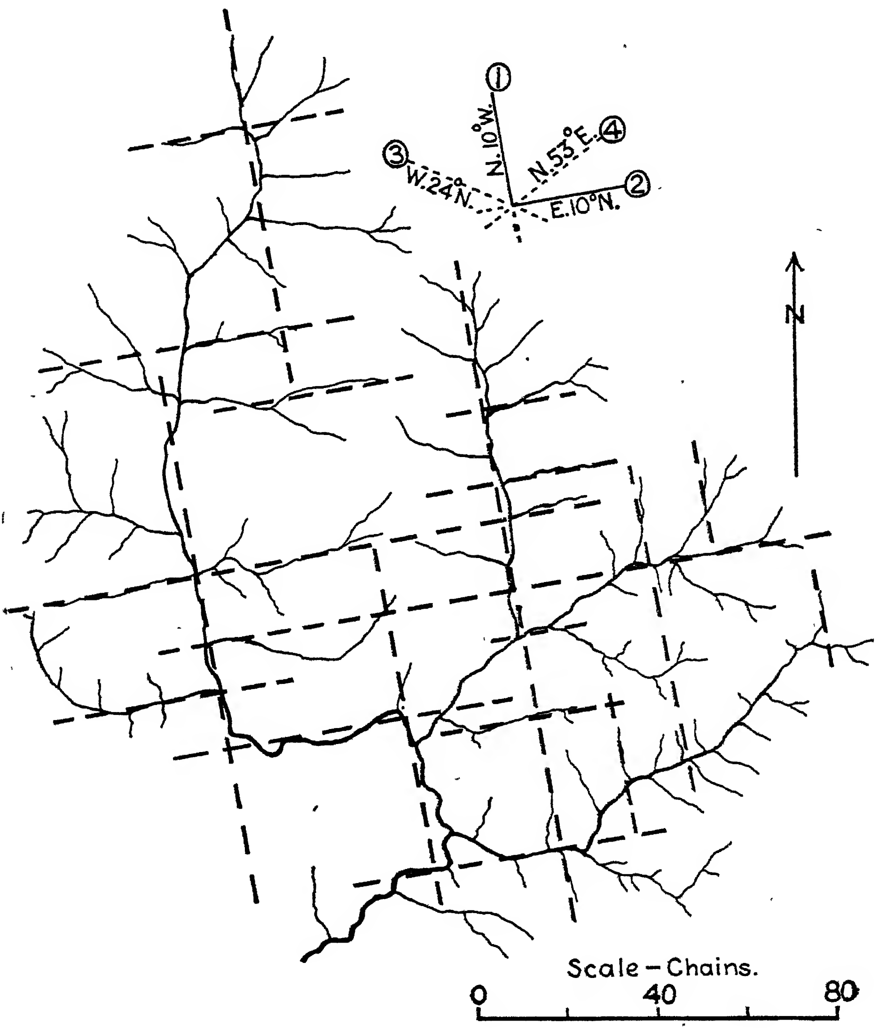


Fig. 33.—"Drainage Network," of Back Creek, Greendale, showing the possible influence of the rock structure of the lower ordovician rocks through which it flows. The strike of these rocks is approximately North, and East-West dykes and fractures are numerous.

and east 24°S. No evidence for this was especially looked for in the field, but Hobbs (ref. 32, p. 56) suggests that the "master-joints" of a crushed block are intersected by another set at about 45° to the first. (See also Fig. 242, ref. 32, the "pattern" of the stream shown in Hobb's figure has a peculiar resemblance to that of Back Creek).

Korobeit Creek rises near Mt. Blackwood, and has been influenced in its upper parts by the Blackwood basalts. It flows south and west through Ordovician, later tertiary gravels, and older volcanics (including tuffs), in a wide valley that was perhaps already chosen in pre-newer basaltic times, joining Pyke's Creek at the reservoir. This concludes the account of Pyke's Creek and its tributaries.

(e) *Myrniong Creek.*—This stream is wholly post-newer basaltic. Its ancestor, the "ancient Myrniong," flowed down from where Mt. Blackwood now is, entering the "ancient Werribee" not far from the point where the Myrniong junctions with the present Werribee This old valley was filled by a newer basalt flow (Fig. 21), and the "twin streams" of the Myrniong and Korkuperrimul Creeks arose one on either side. The head valleys of the Myrniong are in Ordovician rocks, and are at first somewhat steep, but soon widen out. The stream flows south, keeping the lava flow of Mt. Blackwood on its eastern bank, and with a variety of older rocks on its western side. At the village of Myrniong, in response to a western bend in the basalt tongue, it also turns westward, and then south. It then enters granitic rocks, which being much decomposed are here, less resistant than the newer basalts. About a mile south of Myrniong it cuts an old basalt-filled river-bed, and thence continues flowing directly towards the Werribee. A little distance further along the stream again meets a deeper tongue of basalt, filling an old valley in the granite, and this gives rise to a most peculiar, though small, physiographic feature, shown in Fig. 34.

This peculiar loop in the Myrniong occurs where it comes in contact with the basalt, which it has not yet quite cut through. It takes a long course through this basalt, doubling right back on itself as shown in the figure. High cliffs occur where the hachures art darkest. The country rock here is granitic, and just over a low ridge, a few hundred yards from the southernmost point of the loop, is the gorge of the Werribee, 300 or more feet deeper. Why the Myrniong chose to turn here, across this very resistant obstruction, and to flow to the Werribee in the present long loop-like course, is difficult to say. It would have been much easier and

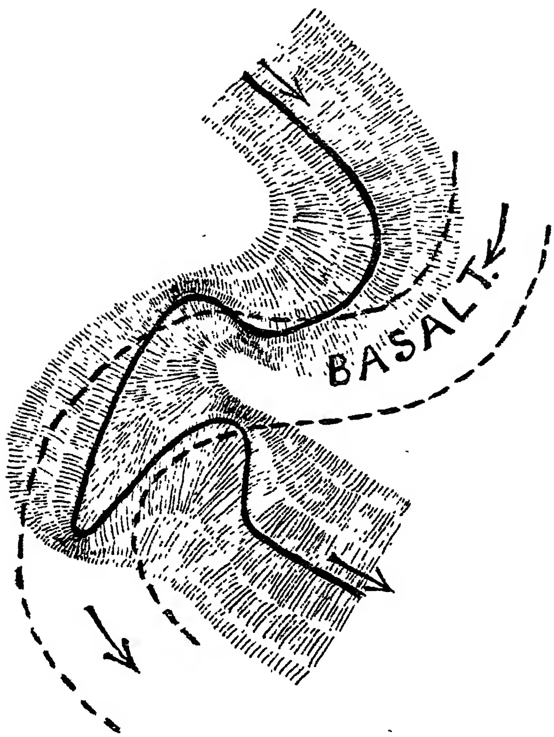


Fig. 34.—Plan of an interesting, though minor, physiographic feature on the Myrniong Creek, where a bar of basalt, filling an old stream valley, crosses the present stream course. Outside the basalt, the rock is granodiorite. Below this bar the grade of the Myrniong steepens rapidly.

more direct for the Myrniong to have continued straight on to the Werribee without cutting through the obstructing basalt. There are two possible answers to the question. Firstly, the basalt sheet may then have been much more extensive, and the Myrniong, flowing on that sheet, might have been pledged to its present course before it had cut down and "discovered" the present obstruction. Or, secondly, and more probably, the Myrniong really did once, in its early days, flow direct into the Werribee at the place mentioned, and was captured by the headward erosion of a small stream, which may have entered the Werribee below the resistant basalt bar that once crossed the latter stream near the eastern end of "the Island." After crossing this bar, the Myrniong runs eastward, looping round "the Island," and entering the Werribee. For this part of its course the valley is very young and steep-sided, with a grade of over 400 feet to the mile. The effect of the ob-

structing basalt bar is very noticeable in the grades of the Myrniong—above that bar the fall is 100 feet to the mile, below it is over 400 feet to the mile.

(f) *Korkuperrimul Creek.*—The upper part of this creek is exactly similar in age and origin to the Myrniong Creek. It flows south for about three miles in Ordovician, with basalt on the right, and high Ordovician on the left. It then turns south-easterly, possibly following the line of the Greendale fault. Into a let-down block of glacial south of this line, the Korkuperrimul then turns its course, and so in a gradually widening valley, and with a gradually lessening grade, it passes through glacial sandstones, older volcanics, and tertiary beds to the Werribee.

That part of the Korkuperrimul that lies wholly in the older basalt is quite steep sided; the characteristic contours are represented in Fig. 10.

The Korkuperrimul, as elsewhere stated, has captured some of the Lerderderg territory. Morton's Creek, flowing in a wide valley through older basalts, and entering the Korkuperrimul on its right bank, is the chief tributary. The last mile of the Korkuperrimul, past Bald Hill, is approximately along the line of the Rowsley Fault, but that feature is now quite obliterated in the extensive erosion of the soft rocks there (See Fig. 30.)

(g) *Goodman's Creek.*—This long and important south-flowing tributary of the Lerderderg must, from the point of view of origin, be considered in conjunction with its "twin stream"—the Pyrete Creek. The area now drained by these two streams was originally the territory of the ancient Bullengarook Creek. When the latter stream was filled by basalt, the two creeks under discussion arose, one on either side. There they have entrenched themselves in deep valleys, with the lava tongue now standing high up between them.

Fig. 16 depicts the origin of such a pair of streams; the facts are of course well-known, but the diagram is intended to give definiteness to the idea. A shows a stream, with a cross-section of its valley. B represents this stream valley, its lower parts filled by a lava flow. In C two "twin streams" have commenced their work, and a further stage is shown in D. It will be noted that both valleys must typically receive their longest tributaries on the sides remote from the flow; this is very distinctly and characteristically seen in the case of Goodman's and Pyrete Creeks. In some cases of course, one stream may for some reason desert the side of the flow, as the Korkuperrimul has done; or one stream

may flow right across the lava tongue, as has happened in the case of Turritable and Willimigongong Creeks at Mt. Macedon. The ultimate result must of course be the total destruction of the lava tongue, with the possible formation of one stream again, but such a stream should itself have a characteristic shape that would indicate its mode of origin. Possibly none of the post-newer basaltic streams in Victoria have yet reached that stage.

Goodman's Creek has a fairly steep and even grade; it flows mainly in Ordovician, parallel to and below the northern continuation of the Rowsley fault. A long, high scarp of tree-covered Ordovician hills bounds the western side of Goodman's Creek, while the Bullengarook basalt limits the eastern side of its valley. A large number of important tributaries come down from the western ranges; a few very steep gullies enter on the east. The lowest of the three western tributaries shown in Plate XII.B flows, in its W.-E. portion, along the Coimadai fault, between Ordovician and glacial. For the remaining two miles of its course, to its junction with the Lerderderg, Goodman's Creek lies in glacial rocks, in a wide valley, with gentle grades.

(h) *Pyrete Creek.*—This is also known as Coimadai Creek. It rises in the deeply ravined block of high Ordovician east of Mt. Bullengarook. The tributaries that lie in these ranges are pre-newer basaltic in age, with the possible exception of subsequent minor captures, and no doubt belonged to the ancient Bullengarook Creek. The main part of the river is, however, post-newer basaltic, as already described. A vigorous attack is being made on the lava tongue where it bends westward, and the old river gravels are here exposed in three places; where seen these gravels are iron-cemented and very coarse. The extensive "bight" in the Bullengarook basalt tongue (Fig. 22) does not represent the original outline of the flow at that point, but is mainly due to the erosive work of the Pyrete Creek. The river is in Ordovician as far south as the village of Coimadai; here it crosses a small fault (see Fig. 5), and enters on an area of glacial sandstones and conglomerates, and tertiary limestones and clays. It occasionally cuts through these to the Ordovician bedrock beneath, exposing in places the beautifully striated permo-carboniferous glacial pavements described by Officer and Hogg (ref. 43), etc. For the last few miles the river has cut through the newer basalt and tertiaries, exposing low-level Ordovician slates. It finally enters the Bacchus Marsh basin and flows across the alluvial flats to the Werribee. The grade of this creek, as plotted in Plate XIIA., shows traces of

two "breaks," with steeper grades, apparently due to the two E.-W. faults that lie in its course.

(i.) *Djerriwarrh and Toolern Creeks.*—These two streams did not receive the close attention given to other streams described. The Djerriwarrh is locally known as Deep Creek, and the Toolern is shown in some maps as the Toolam Toolern. The Djerriwarrh receives a fairly important tributary—Boggy Creek—on its right, while the Toolern receives Condon's Creek (sometimes called Yangardook Creek) on its left. Their grades, as shown in Plate XIIA., and their general appearance in the field, bear witness to rejuvenation in their upper portions. In this rejuvenation differential uplift and lava flows have each played a part.

The Djerriwarrh Creek lies wholly in Ordovician, except where its extreme upper tribuaries flow over the Gisborne basalts. Its profile (see Plate XIIA.), indicates that while it is wholly in Ordovician rocks, as far as known, yet these rocks stand at two distinct levels; this profile has been already used as evidence in favour of a fault junction separating the higher deeply-dissected Ordovician, from the low relief area to the south. On the evidence of the contour maps, and without having personally examined that particular portion of its course, the writer would point out the high possibility of the head gullies of the Djerriwarrh Creek having been captured by the Pyrete Creek.

The Toolern Creek in its head gullies has partly cut through the basalts to the Ordovician bedrock, but the greater part of its course lies on the newer volcanics. The writer travelled along it, but found no features of particular interest. Where it passes through the township of Melton, on the Melbourne-Ballarat road, its valley is scarcely perceptible, but it rapidly deepens after crossing the railway line, and enters the Werribee at Exford in a steep-sided valley, wholly basaltic.

(iv.) *The Buried Rivers.* (*Pre-Newer-basaltic.*)

We have no means of discovering the nature of these old river courses beneath the volcanic plains of the Port Phillip sunkland. The bores put down in and near the township of Melton suggest that "deeper ground" exists from the Djerriwarrh Creek towards the Toolern Creek, but the sub-basaltic area here was evidently of very low relief, with widespread gravels and clays; and no definite valleys were detected. Bores and shafts at Altona Bay and Newport show that, under the basalt, there are hundreds of feet of tertiary material, marine and fluviatile, with bedrock at about 400

to 500 feet. At Lara, towards the southern end of the plains, a bore passed through 376 feet of gravels, limestones and clays of tertiary origin. The general level nature of these volcanic plains, except where interrupted by the very ancient residuals of the You Yangs and Anakies, suggests that the underlying surface was also of very low relief, while the evidence of the bores, etc., testify that this surface was composed mainly of marine and estuarine materials (tertiary).

The writer visited the "basalt caves" south of the Parwan railway station. These as far as explored were wholly in basalt, and were formed by the collapse of basalt blocks into some older cavern. It may be that this older cavern was an "inter-basaltic cave," formed by the flowing away of the molten interior after the outer parts had cooled; or it may be that, as at Mt. Mary, limestones occur below, in which underground waters have dissolved out a cavern, and into this some of the overlying basalt has subsequently collapsed. No positive evidence was to be seen in favour of either hypothesis. This is the sum of our knowledge concerning the buried river system of the Lower Werribee plains. This area is therefore left out of our present considerations.

The Blackwood Ranges have been shown to be but slightly affected by the newer volcanic sheet, and that area, too, may be largely left out for the present. We have to consider, then, the central part of the area, containing the main plexus of this river system, as it is drawn in Fig. 35. On this is set out all we have learnt concerning the ages of the present day rivers and creeks, as detailed in the preceding pages. It will be seen that the great majority of the present streams are, without doubt, wholly post-newer basaltic; their present valleys being cut through that rock. These are shown by dotted lines.

In a few cases it is doubtful whether or not the courses were established prior to the newer basalts; such streams are put in with dots and dashes, and thus they must be left until some evidence is found. In yet a third series, the present river courses are still almost the same as were established in pre-newer basaltic times, and are marked with an unbroken line of arrows. These last-mentioned streams indicate something of the trend of the old drainage system; the Lerderderg strongly suggests that the main slope here lay south-easterly.

Our work lies now in those areas where newer volcanic rocks at present occur. In endeavouring to find out the secrets of the rivers

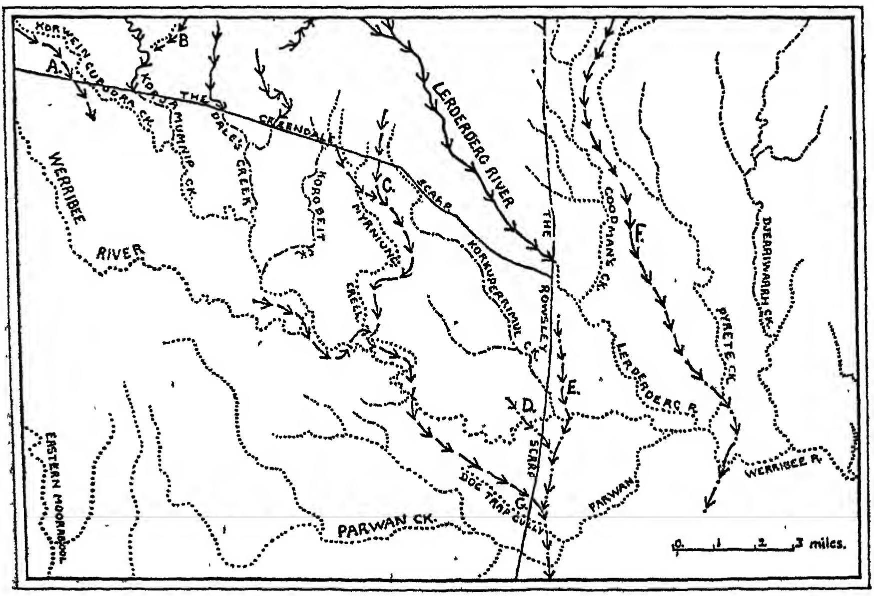
hidden there we may adopt two different methods, according to the nature of the basalt distribution :—

(1) If the basalt is discontinuous, occurring in long tongues, it may and practically always does mark the course of an ancient valley.

(2) If the basalt is a wide sheet, we may search in our present river gorges and cuttings for exposed sections of the buried valleys.

The first method is very simple, and many references have already been made in this paper to the old valleys thus disclosed. These instances will be briefly recapitulated, with reference to Fig. 35, and some fresh cases added.

It may be stated that a lava flow, now almost destroyed, accompanied the upper part of the present Werribee, at least to a point parallel with Egan's Hill. Thus the upper Werribee was also the site of a pre-basaltic valley. While the basalt referred to in this paragraph, as well as much of that towards the village of Korweinguboora, is usually regarded as belonging to the "newer



PRESENT RIVER COURSES: a. developed prior to Newer Volcanic period; b. " since " " "; c. doubtful

ANCIENT RIVER COURSES: (pre-Newer Volcanic) a. still persisting; b. demonstrated; c. suggested

Fig. 35.—Plan showing the present and pre-newer basaltic streams of the central portion of the Werribee area, with other details concerning same.

basalt" series, there is no proof that this is the case; the amount of dissection and decomposition rather favour a greater age in many cases, but as already pointed out, such evidence is by no means conclusive.

West of Ballan, near Bradshaw's railway station, there was an old shallow east-flowing valley. This will no doubt be important when read in conjunction with what evidence the Moorabool gorges have to show, but alone it does not help our discussion.

At A, Fig. 35, we have a basalt tongue marking a buried valley, down which a deep and large stream flowed south. We may call it the Ancient Korweinguboora, since its territory is now drained by a creek of that name. This valley has also been proved by bores, just below the line of the Greendale fault. It had a south-easterly trend, but we do not know where it went beyond that part of its course shown in Fig. 35. The buried river valleys are in each case marked by a broken line of arrows in that figure.

At B, (Fig. 35), a small tributary of the Korjamumnip, the ancient Green Hills Creek, is also preserved under a newer basalt flow. These buried gravels were worked for gold, with much success.

At C (Fig. 35) we have the valley of the ancient Myrniong, filled by basalt, and already frequently referred to. There are no doubts as to the existence and direction of this old valley as far as the village of Myrniong. (See also Fig 21.) Beyond that our second method will be applied.

At D (Fig. 35) there is a small cap of basalt on Trig. Hill. It overlies waterworn gravels, and there appears to be a definite slope in its lower contact line. It is suggested that this basaltic cap marks the site of a small tributary valley that once flowed south-easterly through that point.

At E (Fig. 35) there is a long tongue of basalt reaching up to Bald Hill. It crosses the Werribee at a low level, and has already been referred to. It is underlain by waterworn gravels, and the writer believes it marks a south-flowing tributary. The present arrangement of the basalts of the locality suggests that, while the Trig Hill capping now stands about 400 feet higher, in pre-fault times the basalt may have simultaneously extended up the two valleys.

At F (Fig. 35) we have the ancient Bullengarook Creek, with its suggested southern continuation, while at G we have important evidence of a slightly different nature. At this point we are above the scarp, on that part of the plateau where the Melbourne-Ballarat

railway runs. The basalt sheet may here be regarded as continuous, and yet we have evidence of a "tongue," the latter being exposed by the dissection at Dog Trap Gully. Along the right bank of this gully we see the basalt as a thin sheet covering the tertiary materials. On the left bank, basalt continues right to the bottom of the gully, and it is clear that Dog Trap Gully has cut its valley just alongside a large ancient basalt-filled valley. This old river flowed right across where the scarp now is, and it is difficult to know its exact course on the other side of the fault line.

The Parwan has cut right through the basalt sheet in the lowest part of its course, and the writer knows of no exposed basalt-filled sections there. There remains only the hard bar of basalt that the Parwan is still engaged in cutting through, just below the scarp, and in the reconstruction (Fig. 35), it is suggested that the ancient and important stream now being discussed turned southward there as shown by the arrows.

We have now, for comparison, two basalt-filled rivers crossing fault lines: (i.) the ancient Korweinguboora Creek, as already described, and (ii.) the case mentioned in the preceding paragraph. While in the former case the surface of the basaltic tongue maintains an even gentle grade right across the fault line, in the latter the surface of the basalt descends steeply for over 300 feet.

The second method of discovering ancient river beds is perhaps of greater interest, namely, to piece together the known sections of old valleys exposed in present river cuttings. The most complete evidence of this nature is to be found in the area of deep dissection in the neighbourhood of Werribee Gorge, and Fig. 36 represents that locality on a larger scale. Twelve separate old river sections are shown in this diagram, numbered 1 to 12.

The writer is greatly indebted to Mr. C. C. Brittlebank for a knowledge of the majority of these sections. That gentleman generously spent a part of his vacation in the field with the writer, conducting him to such places of interest as might be of value from the physiographic standpoint, and giving freely of his intimate knowledge of the whole Werribee area.

Nos. 1 and 2 (Fig. 36) are exposed in the valley of the Werribee about a mile above its junction with Pyke's Creek. The Werribee valley is here about 200 feet deep, but it has not yet cut quite through the basalt tongue. The old river valley section is well shown; it is cut in granodiorite, is probably about 150 feet deep, and with moderately sloping sides. A little higher up a small tributary valley came in from the west.

Nos. 3 and 4 (Fig. 36) are exposed in the Werribee not far from the western end of "The Island." The deep, present valley of the Werribee has here cut completely through the old valley, and the section exposed is similar in nature to Nos. 1 and 2, as are all the others as far as is known. Near section 3 a small tributary entered the ancient stream on the right bank.

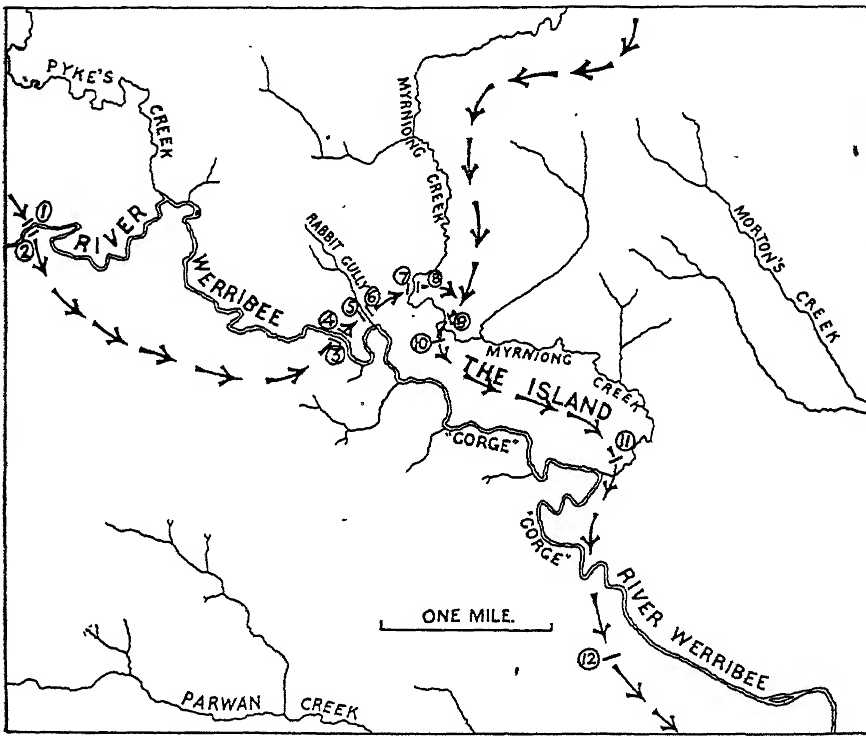


Fig. 36.—Plan to show locations of the various exposed sections of the "Pre-basaltic Werribee," as detailed in the context. With acknowledgments to C. C. Brittlebank.

Nos. 5 and 6 are exposed in a deep little valley called Rabbit Gully, and are likewise in granodiorite. Nos. 7 and 8, exposed in the valley of the present Myrniong, are not quite so clearly shown as the others described, but are nevertheless quite definite. The sections mentioned may be clearly linked up from an inspection of the surface distribution of the basalt, and the reconstruction is shown by arrows in Fig. 36. From its proximity to the present Werribee valley we may call this the "ancient Werribee."

Beyond sections 7 and 8 this stream junctioned with the "ancient Myrniong," and turned southerly to where sections 9 and 10 are exposed in the Myrniong, (Fig. 34). These have already been fully described; the Myrniong has not yet completely cut through this "tongue."

The ancient Werribee then turned eastward, and for the next mile its basalt filling has given rise to the well-known "Island" (see Fig. 20). Section No. 11 is shown at the eastern end of the Island, and a gap of one mile then occurs between sections 11 and 12. This gap is caused by the extensive erosion of the Werribee Gorge, but at least four small relics of basalt may be found along the line of the ancient valley here. A critical inspection of this rugged and difficult area from various viewpoints, and an examination of levels bring one to the conclusion that the course of the old river was approximately as shown by the arrows in Fig. 36. The old valley here was in Ordovician and glacial rocks. Section No. 12 is somewhat obscured by hill-slip material, but basalt occurs in situ at a low level, and from this point south-easterly the evidence of the sections may be linked up with that of the tongue exposed at Dog Trap Gully.

The whole of the available evidence from these sections is summed up in Fig. 36, and the course of the ancient Werribee is shown by a series of arrows, extending from section 1 and 2, right along to the scarp at Dog Trap Gully, a distance of eleven miles.

This knowledge has also been included in Fig. 35, and the rivers there marked by lines of arrows (both continuous and broken) show the pre-basaltic river system as far as the writer could determine it. While there are still many gaps, it is clearly shown that the river system was, south of the Greendale scarp, in an area of fairly low relief, with a general south-easterly trend.

(c) *The Plains and Swamps.*—Plains form no part of block A (the Blackwood and Lerderderg Ranges), nor of the eastern part of block C (the Brisbane Ranges), nor yet of block D (the Gisborne highlands).

Blocks B. and E. however, the Ballan and Port Phillip sunklands, are mainly plains. The only extensive level areas are those of a constructional type, built up either of—

(i.) Volcanic sheets.

(ii.) Alluvial material.

(i.) *Volcanic Sheets.*—The wide, open, grassy plains north and south from Ballan are of volcanic material. They were once much more extensive, and are being gradually destroyed by the rivers,

especially by the Parwan, the Werribee, and the Moorabool. Swamps are rare, only a few being known to the writer, one of them in a peculiarly interesting position. It has been mentioned that the divide between the Moorabool and the Werribee is mainly very low. Just west of Ballan, the Geelong water race from Korweinguboora traverses this divide in a trench a few feet deep.

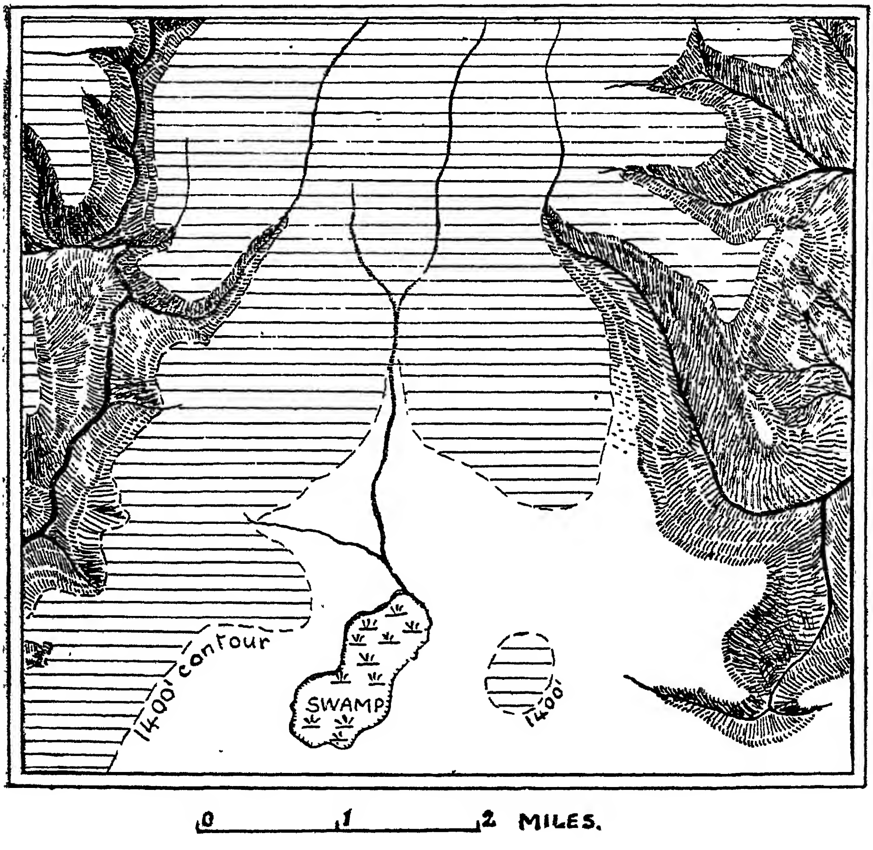


Fig. 37.—Plan of Swamp near Mount Wallace, showing nature of the divide between the Parwan Creek and the Eastern Moorabool. To illustrate some phases of the post-newer basaltic development of drainage, and also the nature of the divide between the Werribee and Moorabool basins in this locality. The Parwan is in the east of the plan, the Moorabool in the west.

Further south, below Mt. Hydewell, and immediately north of Mt. Wallace, the swamp occurs which is the subject of Fig. 37. To the west the Eastern Moorabool has entrenched itself in a gorge

about 200 feet deep, while on the east the Parwan tributaries run steeply down to a depth of over 600 feet. The area between, less than three miles wide, is almost level, and both streams have small tributaries heading back to within a mile of each other. This level tract is a remnant of the once more extensive newer basalt sheet, and the part shaded horizontally stands above the 1400 feet contour line. A shallow south-flowing valley has chosen a central course, midway between the two competing streams and in the part left unshaded in the plan (between 1350 feet and 1400 feet) it forms a swamp in winter. (Fig. 37).

There is no doubt that we have here a case of (geologically) imminent capture. The southern bounding fault of the Ballan sunkland passes E.-W. through the central part of the swamp (beneath the basalt sheet). South of that line the bedrock is hard Ordovician, while to the north the basalt is underlain by the soft tertiaries. The capture should therefore take place to the north of the swamp, probably about the point where the two hachured tributaries most closely approach each other. The Parwan headwaters here have a much steeper grade than the Eastern Moorabool tributaries; both sets of streams are dry for the greater part of the year. Again, speaking geologically, we may look forward to the capture of the Eastern Moorabool by the Parwan even earlier than is suggested by Mr. Hart (ref. 22, p. 269).

The next great expanse of plain is that of the Lower Werribee ("Iramoo.") This aboriginal name was probably originally applied only to the more northern portions of the plains. These plains are wide and bleak, and are almost wholly volcanic, in places overlain by later alluvium. Here and there are small patches of timber, mainly box-trees, but these are most likely on places where an area of alluvium provides the necessary depth of soil. There is a general slope to the sea (see Fig. 12), and swamps are fairly common, especially close to the coast-line. The drainage is, of course, young, and is effected by the Werribee with the Skeleton Water Holes and Kororoit Creek to the north, and Little River, etc. to the south. A chain of swamps crosses the Bacchus Marsh-Geelong road, between Bald Hill and Parwan, and testifies to the backward stage of the drainage system in this portion of the plains.

The idea is put forward by Kitson (ref. 37) that the sea once extended over these plains, and that much of the lava was submarine. He bases this on the thickness and extent of pebbly drift, such as may be seen in exposures at Exford, etc. Examination by

the writer showed nothing to suggest a marine origin for these gravels, and they are no doubt part of the material carried down from the western lifted blocks, and spread out over the plain before the Werribee had established its present valley. Even in the much deeper deposits at the town of Werribee, the only fossils found are those indicating fresh water.

(b) *Alluvial Plains.*—These are wholly confined to the Lower Werribee, excepting those on the western part of the upland block that forms the Brisbane Ranges. The latter, however, are more intimately connected with the physiography of the Moorabool basin. In the west of block E, these alluvial sheets spread out from the base of the Brisbane Ranges, and extend southward, embracing the You Yangs. It should some day be an irrigated area.

The triangular patch of deep alluvial, overlying basalt, which extends from the mouth of the Werribee up to the town of the same name, is an important agricultural district. This extensive irrigation settlement has suffered much in the past from the failure of the main storage reservoir, but it is confidently believed that this trouble is now over. Freshwater unio and fossil bones (Quarter Sheet 20 N.-E.) have been found in the alluvial of this area, which was doubtless formed under estuarine conditions at a comparatively recent date, when the general level of the land was somewhat lower than at present.

(iii.) *Bacchus Marsh Basin.*—The question of the origin of this important feature is one of some difficulty. Fig. 38 has been drawn to show the nature and extent of the basin. As we see from that sketch, there is about six and a-half square miles of flat country, with deep and rich alluvial soil; a more exact estimate gives about 4500 acres of irrigable land. The flats are formed where the most important tributaries of the Werribee all meet together. Thus we have in our sketch the Werribee, Korkuperrimul, Lerderderg, Goodman's, Parwan, and Pyrete all assisting in the building of these flats. The complex formations of the surrounding highlands, rich volcanics, sandstones, clays, etc., all send their tribute to be blended together for the building up of the wonderfully fertile soil of "the Marsh." The greater part of the work done in forming the Bacchus Marsh basin is apparently due to the Lerderderg. Close to the lowest "flats" are various slightly-elevated pebbly river terraces, and as we cross the bounding line between the two formations, we pass from land worth £80 an acre to land worth £2 10s. or less per acre. This is especially the case on the southern side of the basin, the higher ground on the western slopes having somewhat better values.

As already mentioned, Bacchus Marsh lies in a basin. To get out from this basin by road in any direction, it is necessary to ascend. The Werribee River makes its exit at the south-eastern

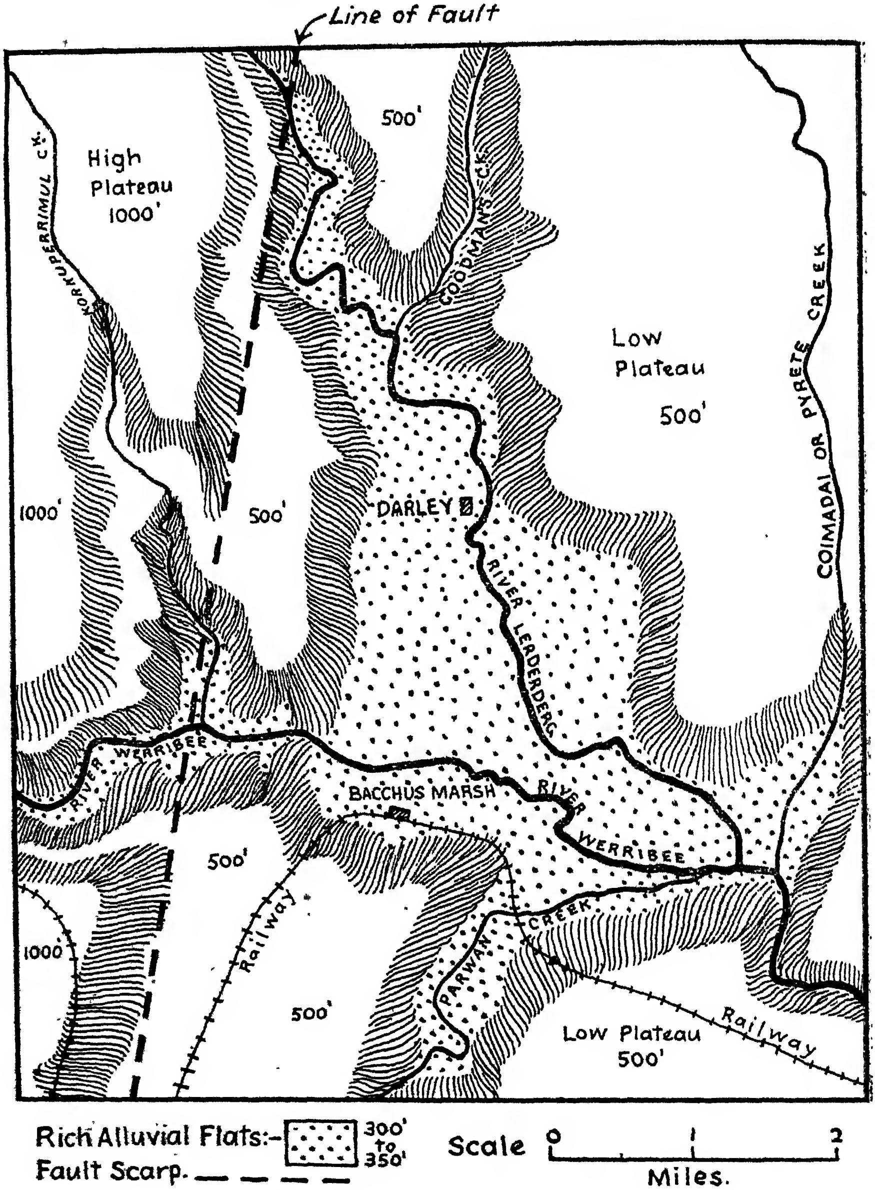


Fig. 38.—Plan to show the nature and extent of the Bacchus Marsh Basin, as described in detail in Section IXc.

end of the depression, through a gorge so narrow and deep that it cannot be availed of for any line of communication (see Fig. 38).

That this basin has been carved-out by the rivers mentioned above is beyond dispute. It is easy to understand how, once the basin was commenced, the rivers would gradually extend it further outwards and down-stream, by "side swinging." The commencement of the basin was probably made by the Lerderderg and Werribee at their point of junction below the fault scarp. That junction must then have been at a point somewhere west of the town of Bacchus Marsh, and at a higher level than the present flats.

Hart (ref. 22), after discussing the erosion of the Parwan valley, says: "A similar explanation can be applied to Bacchus Marsh itself." It appears to the writer that there are important differences in origin between the Parwan Basin and the Bacchus Marsh basin, although the rocks worked in are closely similar. The Parwan Basin is on the up-throw side of the fault line, with the accompanying rejuvenation of its streams. The Bacchus Marsh basin lies on the down-throw side of the fault, where aggradational work would be done by the rivers, possibly until such time as the Lower Werribee established a channel in the newer basalt. The Parwan basin has been mainly accomplished by the *headward* erosion of steep tributary valleys. This can hardly have been the case with the Bacchus Marsh basin.

If the newer basalt covered the Bacchus Marsh area right up to the scarp, it is perhaps less easy to conceive how the start was made towards the formation of the basin and the flats. The preliminary factors that led to the origin of the Bacchus Marsh Basin may be stated thus:—

(1) The probable meeting near to and south of Bachus Marsh of at least two important pre-basaltic streams, the "ancient Werribee" and the "ancient Bullengarook."

(2) The filling of these valleys with newer basalts, which also spread out, covering much of the adjacent country, and overlying easily-eroded, level-bedded sands and clays.

(3) The meeting together of several important streams, on this area.

As the rivers, above the scarp, carved fairly deep gorges (see Fig. 30), they would also cut valleys through their own alluvial deposits at the base of the scarp, and, later, into the rocks below. Since the only course for these rivers was across the volcanic plains to the south-east, a channel was developed there in the basalts. As the lower part of the stream gradually deepened

its valley in the hard basalt, the Lerderderg, Werribee, etc., in the neighbourhood of Bacchus Marsh would find time to widen their valley in the softer rocks, and then to meander in that valley, and so to form a "basin." The tendency would be to extend the basin down-stream by meanders, etc., undercutting the basalt sheet, which here overlies very soft sands and clays; thus the basin would be enlarged to embrace the junctions with the Parwan and Pyrete Creeks. Most of the work has been done subsequent to the rivers cutting through the basalt into the clays, etc., below. An examination of the limiting eastern wall of the basin, to the south and north of "Anthony's Hill," assists in confirming this view.

Remnants of the old apron of alluvium are still to be found in extensive coarse pebbly terraces that occur at different levels all along the western margin of the Bacchus Marsh flats. The soil of these terraces is much poorer and more difficult to irrigate than that of the "flats."

A smaller basin, quite similar in nature and origin to the Bacchus Marsh basin, occurs to the west of Bacchus Marsh, at "Blink Bonnie" farm. Here Lyell's Creek (the Korkuperrimul) and the Werribee meet behind a small lava tongue, which they have now quite cut through. The narrowing influence of this tongue of hard rock, with the flats formed in the softer rocks upstream, may be well seen in the field, and is suggested in Fig. 38.

Bacchus Marsh is so named after Captain W. H. Bacchus, who settled here with stock in 1838. Old maps show an area of marshy land near by, on the Lerderderg River, less than a mile from the place marked "Bacchus Station" (see Quarter Sheet 12 N.E.). No trace of this marsh now remains as the land is all drained and tilled—there is scarcely any doubt, however, that this marshy area gave the name to the locality.

X.—Economic Importance of the Physiographic Features.

The economic bearing of the various physiographic factors has been borne in mind throughout the paper, and frequently referred to. In this section the matter will be dealt with in the undermentioned order. Reference to the sections shown in Figs. 12 and 13, and the block diagram (Fig. 40), will be found helpful, while the large map (Plate XI.) has been specially drawn to illustrate this portion of the paper.

(a) Communications—Roads and Railways.

(b) Water Conservation.

(c) Population and Occupations.

(a) *Roads and Railways.*—The chief lines of communication in the Werribee area lie along the level plains of the Ballan and the Port Phillip Sunklands. The road and railway from Melbourne to Geelong both cross the lower Werribee plains, with that directness that characterises roads, etc., in an area of easy grades. Numerous other roads criss-cross the Werribee plains providing easy communication between Melbourne, Bacchus Marsh, Melton, Balliang, Little River, Werribee, Anakie, Geelong, etc. These roads are all in fairly good order, the main roads especially so.

The Ballarat-Melbourne railway and the main road between the same centres had of necessity to ascend the formidable obstacle of the Rowsley or Bacchus Marsh scarp, since that feature stands normal to the line joining these places, and extends for many miles to the north and south. The reality of this barrier is also suggested by the fact that the main or only communication between Ballarat and the seaboard was, for many years, through Geelong, along a route that avoided the scarp. This statement is based on the writer's recollections of the reminiscences of numerous pioneers of the "digging days," the early fifties; the chief mode of transport to Ballarat and the neighbouring diggings was, in those days, "by bullock dray from Geelong."

The grades above and below the Rowsley scarp present no difficulties, although the dissection of the upland "plains" has caused the present railway line to bend somewhat in places. The ascent of the scarp is made at Bacchus Marsh, where that feature is lowest. The train climbs the 1300 feet between Bacchus Marsh and Ingliston partly by means of a long loop, high grades prevailing all the way. The present road has been selected along the valley sides to the north of the Werribee, where the scarp is deeply dissected.

The roads from Melton to Gisborne, and from Bacchus Marsh to Bullengarook, both contain very steep pinches, where ascending from the plains to the uplifted block. Both roads are selected largely along basaltic flows, but neither is greatly used.

No road leads from the lower plains on to the Brisbane Ranges, excepting a very poor and little used road at the Anakies. The grades are high, and the scarp is possible of ascent here only because of the accumulation of the volcanic material of the Anakies close against it. An old railway survey also chose this route.

Communication within the Ballan sunkland is comparatively easy, and good roads are numerous. An exception occurs at the eastern end, where the agricultural area of Myrniong and Pentland Hills is cut off from the railway by the deep gorge of the Werribee. Their only outlet is via Bacchus Marsh, and this difficulty is a severe handicap to those concerned.

The uplifted block of the Blackwood and Lerderderg Ranges is almost roadless, although timber-getters and gold-miners had "tracks" in various directions. When Blackwood was a flourishing mining field, supplies were brought from Melbourne with difficulty; one track much used in those days took advantage of the gentler grade of the Mt. Blackwood lava flow, and then travelled along the ridge shown in Fig. 18, turning down into the valley of the Lerderderg at Blackwood. Another road climbs the scarp near Greendale, travelling up along the side of a small valley known as Long Gully, and then following the uneven ridge which separates the Back and Dale's Creeks. This is still the chief way of reaching Blackwood from the south, and is a very poor road. The best way to reach Blackwood is by a rather good road that winds down into the valley of the upper Lerderderg from the Main Divide, to the north. A short road runs northward across the Greendale Fault line to Blakeville, following mainly the newer-basalt tongue there. The difficulties of communication in this area are illustrated by the fact that one of the surveyed railway routes shown on the map (Plate XI.), from Ingliston to Bullarto, was estimated to cost £17,568 per mile, more than twice the average cost of the other projected routes shown. The townships on the Main Divide (Bullarto, Garl'ick's Lead, etc.), all have their chief or only communications to the northward. The main road that leads into the steeply-enclosed basin of the Parwan valley is of some interest; one would naturally expect it to follow the stream, but the narrow passage through the basalt at the edge of the Rowsley scarp makes that route quite impossible, and the road therefore climbs over the ridge somewhat to the south of that point. At least four other roads lead out of the Parwan valley, but they are practically impossible for ordinary traffic. The effect of the high ridge that now marks the long-reaching Bullengarook basalt flow is seen in the two old railway surveys that crossed that ridge west of Coimadai; long loops mark the location of the basalt-capped ridge. (Plate XI.) The importance of the abundance of basalt (for macadamizing) in most parts of the area has of course an important bearing on the nature of the roads. This fact is particularly

noticeable when travelling in these localities more remote from the basalt supplies.

(b) *Water Conservation.*—This has already been fully dealt with in the opening sections. The main irrigation areas of Bacchus Marsh and Werribee are shaded in Plate XI., and the two chief storage reservoirs for those areas, at Pyke's Creek and Exford, are also indicated. Good catchment areas on the uplifted blocks still await the construction of storage dams, especially along the Lerderderg, whilst some large areas of level, low-lying alluvial country are yet without irrigation schemes. Rainfall, evaporation, etc., are fully discussed in Section V. (a). The recognition of the "dry belt" there referred to has an important bearing on land values on the lower Werribee plains.

(c) *Population and Occupations.*—The total population of the Werribee area is somewhat under 10,000. Of these the greater number are congregated about three centres which lie on the Werribee River itself—(See Plate XI.)—Werribee (about seven miles from the river mouth), Bacchus Marsh (in the centre of the area), and Ballan (about the centre of the Ballan sunkland).

Two once-important gold fields exist in the area, Blackwood in the centre of the Ordovician block A, and Steiglitz in the heart of the Ordovician block C. Both places are at present under eclipse. Other villages and townships occur, and all will be dealt with below, according to the geographical reasons for their locations, in the following order:—

(i). The lower Plains.
(ii.) Bacchus Marsh and Vicinity.
(iii.) The Ballan Sunkland.
(iv.) Blackwood and Lerderderg Ranges.
(v.) Brisbane Ranges.
(vi.) The Divides.

(i.) *The Lower Plains.*—The towns and villages of these wide basaltic plains are wholly centres of various agricultural activities, but enormous stretches of these plains are still used for grazing only. The rainfall is low, and irrigation is availed of to some extent; markets are handy, and transport easy. A number of villages in this list are not really in the Werribee basin, but are included since their localities have been dealt with in the paper:—

Werribee (Wyndham).—Twenty miles from Melbourne, on railway and main road. Farming and grazing. It is the second centre of importance in the Werribee basin. Two large establishments, the Metropolitan Farm and the Government Research Farm, are

located here, and a large area is irrigated. The military authorities have taken advantage of these level plains for the establishment of the Central Flying School near by. Dr. Taylor has published interesting notes concerning these plains, from the point of view of the aviator, in the Commonwealth Meteorological Bureau reports.

Other small villages on the plains are:—Little River (Bulban), Melton, Laverton, Toolern Vale, Mount Cotterill, Anakie, Balliang, Rockbank, Truganina, Tarneit and Exford. Agriculture, with closer settlement, is taking the place of grazing in some areas. The future prosperity of these plains appears to lie in the extension of the irrigation system where possible.

(ii.) *Bacchus Marsh and Vicinity.*—The town of Bacchus Marsh is the chief centre of population in the Werribee basin. It owes its origin wholly to those geological forces that located and built the Bacchus Marsh basin. Irrigation has been wisely availed of, but has suffered much from the failure of the storage reservoirs in the past. The rich soils of the flats are used for dairying, fruit growing, lucerne growing, and general agriculture. The town is attractive, and is a favourite stopping place for travellers. The scenic beauties and scientific interest of the district attract many visitors. The village of Darley lies to the north, and in addition to the rich soils, the faulting has preserved large deposits of fireclays, etc. (tertiary), and fair building stones (permo-carboniferous sandstones). Coimadai township is close by, and its valuable limestone deposits (tertiary) are also due to preservation by faulting, and later exposure by Pyrete Creek. Communication between Coimadai and Bacchus Marsh is greatly hampered by the occurrence between them of the high residual tongue of the Bullengarook basalt flow. A small antimony mine occurs in the Ordovician ranges to the north. Parwan and Rowsley are wholly agricultural and grazing, though good deposits of clays and building sands occur at Dog Trap Gully, near the latter place, and have been extensively worked.

(iii.) *The Ballan Sunkland.*—The varied rocks of this locality (see Fig. 13) provide good soils—newer and older volcanics, glacial sandstones, etc. The population is therefore chiefly farmers and graziers; the newer volcanic plains have but shallow soils in many cases, and are more used for grazing purposes. The town of Ballan itself has grown up chiefly as a centre for the various farming villages around it. Greendale, at the foot of the Greendale scarp, has well-grassed flats, and rounded hills of glacial

sandstones and older basalts. Myrniong has similar soils, and both places are dairying and agricultural localities. Other townships are Ingliston, Mt. Wallace and Bunding—all on the volcanic plains, farming and grazing. There are quarries in the permo-carboniferous "freestones" of Greendale, which are occasionally worked.

(iv.) *Blackwood and Lerderdery Ranges.*—We find in these uplifted masses of bedrock a quite different population. The quartz reefs of the Ordovician and the timber of the ranges attract only miners and saw-millers. Blackwood is the chief township here, and was almost wholly mining—alluvial and quartz. Near by were the townships of Simpson's and Barry's reefs, both wholly mining. The village of Blakeville was largely a timber-getting centre, on account of its position in the ranges, and communication by an easy road to Ballan. Mining was also carried on. The tiny locality of Green Hills, well hidden in the ranges, is interesting. Here a small isolated lava flow covered up and preserved the river gravels of a short valley. This lava provided a limited area of good soils, the buried gravels were mined for gold, and the surrounding ranges were densely timbered; the locality thus became a mining, saw-milling and farming area. The two first-named industries have passed away, and a few farms alone remain.

The fairly dense forests that clothe the Ordovician ranges are for the most part at present closed to saw-millers for regeneration purposes. The great economic importance of these timber supplies must not be overlooked, especially in view of the growing appreciation of native hardwoods.

(v.) *Brisbane Ranges.*—As in the Blackwood ranges, gold-mining is the chief activity, Steiglitz being the main centre. In the western part, where newer basalts occur, there is some farming and grazing. To the south, where a let-down has preserved the younger rocks, tertiaries and older basalts, we get the fertile farming townships of Maude and Sutherland's Creek. The Geelong water supply has two reservoirs in these ranges at Durdiwarrah.

(vi.) *The Divide.*—On or near the Main Divide, where it bounds the Werribee basin on the north, there are three townships—Korweinguboora, Old Bullarto and Newbury (Garlick's Lead). All three are situated on areas of good volcanic soils, and are farming localities. In each case, also, the buried river gravels, below the lava flows, were worked for gold in the past.

XI.—Chronological Record of the Physiography of the Area.

This section is intended to act partly as a summary of the physiographic and geological events referred to in the preceding pages. Fig. 39 is drawn to recapitulate the physiographic history of this area in an "erosion column," analagous to the sedimentation column of geologists. Diastrophic periods of folding and faulting are suggested, and periods of vulcanicity and sedimentation are marked as breaks in the progress of erosion. Leaving out the Port Phillip sunkland, the underlying rocks of which are not exposed in this area, there is no evidence of any extensive marine transgression since the close of the lower Ordovician period. Traces of the "buried landscapes" of various periods are here and there available, and these have been marked in the column. Each geological system was given an approximately equal length of the column, which is therefore not to be regarded as a true "time line."

It will be seen from the column that, following the great lower Ordovician deposition, there has been no further marine sedimentation of any note in this area.

In consideration of the possibilities of various periods of sedimentation having affected marginal portions of the Werribee area, certain of these periods are indicated by small triangular insets on the left-hand side of the column (Fig. 39). Such periods may suggest, however vaguely, something of the general nature of the topography of this area during the long periods of erosion that followed the withdrawal of the sea at the close of the lower Ordovician period.

As already pointed out (Section VII (a)), the lower Ordovician sea or gulf covered the whole of the area here discussed, and extended well beyond its boundaries. Subsequent to the recession of this sea, a further marine transgression occurred in upper Ordovician times. Since richly fossiliferous rocks of this age occur on the Mornington Peninsula (east of Selwyn's fault), and probably below the Silurian at Diamond Creek (ref. 36), it is possible that the shores of this sea lay partly within the Werribee area. Similarly also the later marine encroachment of Silurian times is recorded in the rocks closely contiguous to this area, at and immediately westward of Melbourne.

There is evidence in the folding of the lower palaeozoic rocks that in middle to upper palaeozoic times great ranges of fold moun-

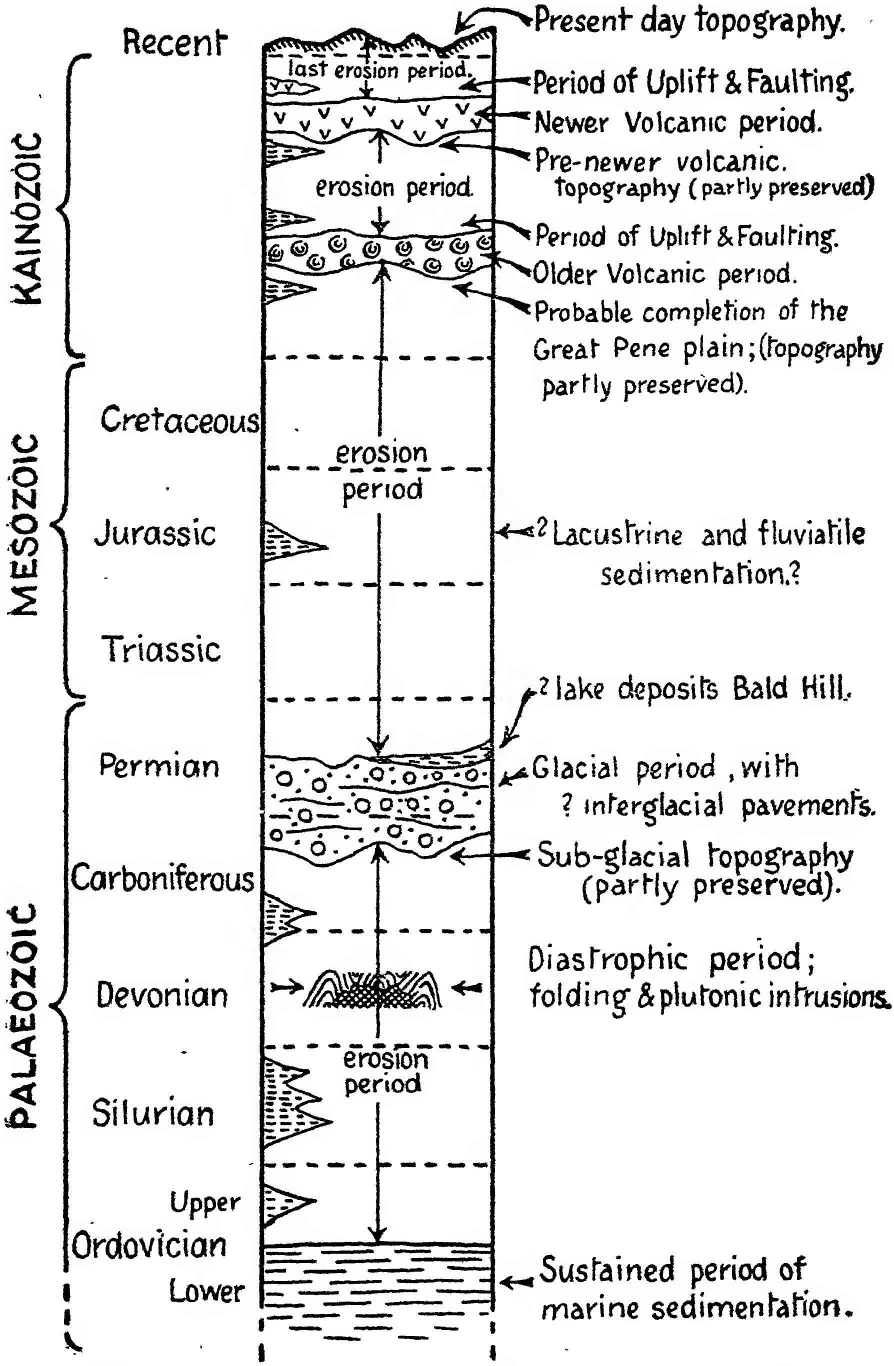


Fig. 39.—Chronological column, recording the order of the physiographic events affecting this area, referred to in detail in Section XI.

tains, running north and south, were built up. Such evidence lies in the intense folding along north-south axes which is associated with the extensive (?) Devonian plutonic intrusions, following similar lines, as shown in Fig. 17. It is of further interest to note that the known relics of the earlier upper palaeozoic physiography, buried under the permo-carboniferous glacial deposits, bear witness to north-south valleys. The possibility of lower carboniferous sedimentation in this area has been discussed in Section VII. (a).

The glacial period was itself an erosive period, but its completion left great masses of morainic material that have been protective of the underlying surfaces, and thus we have preserved in this area relics of the extremely ancient upper palaeozoic landscape, where these valleys have been exposed in section by the present-day streams.

Examples of interglacial pavements (?) were discovered by the writer in the glacial material at the mouth of the Lerderderg gorge (left bank). Probably the post-glacial "lake" deposits (Fig. 39) should be higher up in the column. (Chapman, "Australian Fossils," p. 88.)

The "great erosion period" then continued, with what interruptions we know not, right up to the lower-to-middle tertiary period, when the "Great Peneplain" was completed, and then partly destroyed by the older volcanic flows, with uplift and faulting. To this period belong the Greendale fault (post-older and pre-newer basalt), and the other dominant lines of differential displacement of this area that have been associated therewith. The northern boundary of the basin of Jurassic sedimentation probably lay to the south of our area.

Another period of erosion extended to pre-newer volcanic times, the resulting physiography of which, in this area, is largely preserved below the newer basalts, as shown by the reconstructed river systems in Fig. 35.

The widespread tertiary series of the Bacchus Marsh area are less than 1000 feet in depth, and may be associated with the accumulation of fluviatile material on the lower levels of the peneplain subsequent to the first great tertiary uplift. Three periods of tertiary marine invasion are also suggested in Fig. 39, but none of these affected the Werribee area as a whole.

In placing the various happenings of the tertiary period in the "chronological column," it is not intended to refer them exactly to any particular division of the tertiary period. It will

be understood also that the terms "older and newer volcanic" are used here with the reservations mentioned in Section VIII. (a) of this paper. More definitely, they may be taken as referring to the two distinct periods of vulcanicity evident in the Greendale-Bacchus Marsh area. The positions given to these two volcanic periods in Fig. 39 must be taken merely as a general impression of their relative ages. Subsequent decisions by geologists regarding the exact positions of these events in the tertiary "time-line" should not greatly affect the sequence recorded in this column.

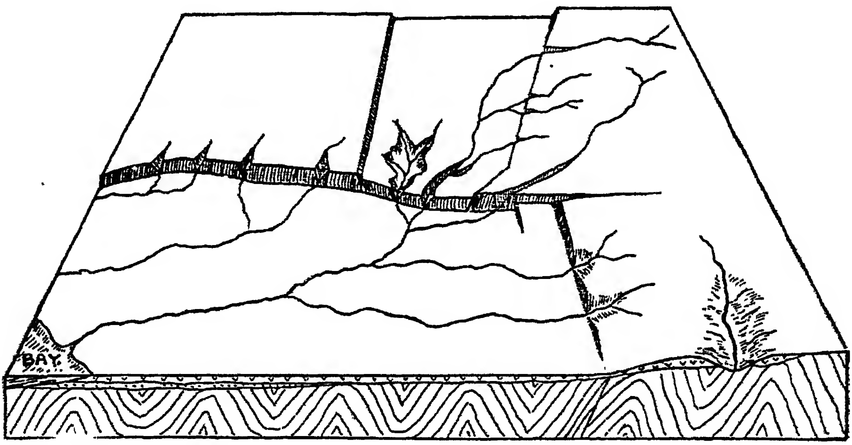


Fig. 40.—Generalised block diagram to show the chief structural features of the Werribee River area.

The great tertiary subsidences that are known to have taken place in southern Victoria, with marine transgressions, should of course be correlated with the diastrophic periods mentioned in this column. While our marine series suggest three great "breaks," evidence of but two of these was found in the Werribee area.

The structural features of the Werribee River basin, extremely simplified, are shown diagrammatically in Fig. 40. This block diagram is drawn as if viewed from the east; it may be taken as a summary of the writer's opinions of the main tectonic features of the topography of the basin, minus the effects of the later lava flows.

The Newer Volcanic period, in later tertiary times, was accompanied by another great series of uplifts, associated in this area with the Rowsley or Bacchus Marsh Fault. Since then the forces of erosion, modified to some extent by every happening that had gone before, produced for us the hills and valleys of the Werribee area as we know them to-day.

XII.—List of References quoted in this paper.

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END OF VOLUME XXXI., PART I.

[PUBLISHED DECEMBER, 1918.]

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II, 1919].

Art. X.—*New or Little-known Victorian Fossils in the National Museum.*

Part XXII.—Palaeozoic Worms; with evidence of Soft Parts.

By FREDERICK CHAPMAN, A.L.S., &c.

(Palaeontologist to the National Museum, Melbourne).

(With Plates XIII. and XIV.).

[Read 8th August, 1918].

Introduction.

This paper is largely concerned with the relationship of the genus *Trachyderma*, Phillips, previously discussed in this series,[1] as seen in the light of some more or less recent discoveries of remarkable, well-preserved gill-plumes (prostomial appendages) of these worms. It thus fairly establishes the claim of these fossil worms, formerly described by Phillips, Salter, Cowper Reed and the writer, to belong to the Chaetopoda and having affinities with the Cryptocephala, to which the sabellids and serpulids are referred by Dr. B. Benham.[2]

The fleshy appendages of the Victorian Silurian worms, as here understood, have generally been referred by collectors to "fucoids," and it was only by the discovery of better-preserved specimens, and their association with tubes of *Trachyderma*, that their true relationship was conclusively made out.

The latter part of this paper deals with the genus *Cornulites*, and the description of a new species in Victoria. So rare is this genus in Australia that only one other species appears to have been previously known, namely, *C. tasmanicus*, described by R. Etheridge, junr., from Heazelwood and Zeehan, Tasmania.

PHYLUM VERMES. Class CHAETOPODA (Bristle-worms).

Sub-class Polychaeta (Marine-worms).

Fam. Trachydermidae, Chapman.

Genus **Trachyderma**, Phillips, 1848.[3]

Notes on the Genus.

Phillips founded this generic type on the "external case or tube (analagous to the 'shell' of *Serpula* and *Spirorbis*). . . .

1 These Proceedings, vol. xxii. (N.S.), pt. ii., 1910, pp. 102-105.

2 Cambridge Nat. Hist., vol. ii., 1896. Polychaete Worms.

3 Mem. Geol. Surv. Gt. Brit., vol. ii., pt. i., 1848, p. 331.

The structure of the covering is, in the arrangement of the incremental lines and rings, more analogous to that of the Serpulidae than to what occurs on other groups of Annelida, or on the fistuliform Radiaria and Ascidiae. It may, in fact, be pretty exactly paralleled on large specimens of Serpulidae."

From figures and descriptions of the various species of the genus—as *T. coriacea*, Phillips,[1] *T. laevis*, McCoy,[2] *T. serrata*, Salter,[3] and *T. squamosa*, Phillips,[4] of Llandeilo to Upper Ludlow (Lower Ordovician to Upper Silurian) age—it is seen that a thick coriaceous tube with a more or less obtusely rounded extremity serve to separate it from Salter's genus *Scolecoderma*,[5] a species of which, *S. antiquissima*,[6] was formerly referred by Salter to *Trachyderma*, but which has a thin membranous tube and a tapering and pointed extremity.

With reference to the scope of *Scolecoderma* as a genus, we may note that there is room for it in its restricted sense, but from Mr. R. Etheridge senior's interpretation it would embrace the earlier described genus *Trachyderma*. Thus, in Salter's Palaeontology,[7] revised by R. Etheridge in 1881, we read:—

"*Scolecoderma*, *Salter*, 1866. Mr. Salter proposed this term for all such membranous tubes (often much compressed) of annelides, found in palaeozoic rocks, as are not clearly referable to the more calcareous, or at least semi-calcareous tubes of *Serpulites*. They are very common. In a few cases it is possible we may mistake impressions of sea-weed for these; but their position in the beds, often vertical or oblique to them, will determine that they do not belong to the algae; and the want of any branches or subdivision of the frond will also tend to determine them. Sometimes they are cylindrical, more often compressed, and we may distinguish this convenient but artificial genus, comprising probably many different genera of annelida from the common *Scolites* by its having clearly possessed a wall or tube which renders the cast easily separable from the matrix, whilst *Scolites* only represents the track of the burrow."

The two species of *Trachyderma* previously met with in Victoria

1 Mem. Soc. Geol. Surv. Gt. Brit., vol ii., pt. i., 1848, p. 331, pl. iv., figs. 1, 2.

2 Brit. Pal. Fossils, 1852, p. 133, pl. *id.*, fig. 13.

3 Quart. Journ. Geol. Soc., vol. xx., 1864, p. 290, pl. xv., fig. 9.

4 Mem. Geol. Surv. Gt. Brit., vol. ii., pt. i., 1848, p. 332, pl. iv., fig. 3. Also *T.* cf. *squamosa*, Reed, Pal. Indica. (N.Ser.), vol. ii., No. 3, 1906, p. 129, pl. vii., fig. 17.

5 Mem. Surv. Geol. Gt. Brit., vol. iii., 1866, p. 292; 2nd ed., 1881, p. 484.

6 Salter, Cat Cambro-Silurian Fossils, 1873, p. 10.

7 Mem Geol. Surv. Gt. Brit., vol. iii. 1881, 2nd ed., p. 484.

have been described as *T. crassituba*, *Chapman*,[1] and *T.* cf. *squamosa*, Phillips.[2] The soft appendages now referred to apparently belong to the former species, though this can only be surmised in the majority of cases from the tubes associated with them.

TRACHYDERMA, sp. cf. CRASSITUBA, Chapm., *et alii specierum.*

General Observations.—In 1910 the writer described two specific forms of worm-tubes from both the Melbournian and Yeringian beds of Victoria. These were referred to the genus *Trachyderma* of Phillips, similar fossils having been recorded from the English Ludlow series and the Silurian of Burma.

These tubes are normally found in the condition of mud-casts, with a harder outer covering, probably originally chitinous or sub-chitinous, of the nature of an organic slime and mud fabric.

No remains of any soft parts of the worms of this generic type seem to have been previously recognised. Many examples, now referred to the cephalic (prostomial) appendages of these tube-building worms, have from time to time been found in the Silurian mudstone of South Yarra and Melbourne by Mr. F. P. Spry, but until lately these specimens baffled all attempts to establish their true nature. Within the last few months Mr. A. James, B.A., B.Sc., was so fortunate as to find, in a bed of this fine-textured blue mudstone, about four miles north-west of Keilor, some beautifully preserved examples of fossil remains similar to those previously referred to as occurring near Melbourne.

That these fossils have a direct relationship to *Trachyderma* is strongly supported by the fact that they are found associated with *Trachyderma* tubes at South Yarra and Keilor,[3] in which deposits they are the only fossils to be found. Moreover, the morphological structure of the impressions and carbonaceous stains, here referred to these gill-like cirri, and which are often surprisingly clear and sharp, resemble no other animal organism, not excepting pennatulids, cirripedes and other like structures. As regards a plant origin for these remains, the single or double series of serrae with a hollow flexuous canal, preclude them from any such reference.

Description of prostomial gill-plumes.—The axis of the plumes is a hollow tube, well seen in more than one example. It is bent

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1 Proc. Roy. Soc Victoria, vol. xxii. (N.S.), pt. ii., 1910, p. 103, pl. xxvii, figs. 1*a*, *b*, 2, 3, ?4; pl. xxix., fig. 1.

2 Ibid., p. 104, pl. xxvii., fig. 5.

3 At Keilor the tubes yet discovered are related to *T. crassituba* in having a thick wall, but it is of a more slender form, and may, on finding further examples, prove to be new. The gill-plumes from the two localities also show slight differences.

in a series of graceful curves, sometimes in a double, sigmoidal or ear-shaped curve, or coiled closely in helicoid fashion. The branchlets are disposed along one face, the inner, except rarely where recurved, and vary in length, being short and stout at the base, to long, flexible and slender nearer the distal end. The outer surfaces of the branchlets are pectinate to filamentous, generally recurved at the tip towards the axis, but occasionally thrown forward. In the blue-grey shale of Keilor the impressions stand out clearly, being of much darker tint. The South Yarra specimens, in yellow shale, are contrasted by bleaching, being paler in tint, or as in the dark blue indurated shale from the Domain Road Sewer, of a carbonaceous shade against the pale grey matrix of the immediate surroundings.

Dimensions.—Length of a large specimen, from the Melbourne district, about 4 cm. Length of another example, from South Yarra, 17 mm.; length of branchlets, 3.5 mm. A specimen from Keilor, 20 mm. long; length of longest branchlet, 12 mm.; depth, 1.25 mm.; depth of thickest branchlet, 3 mm. Thickness of axis about 1 mm.

Evidence of eyes and dorsal appendices.—On one of the best preserved specimens, which has been sharply flexed, can be made out, when held at a low angle to reflected light, some depressions with a central bulb, and partially enclosing it. The axis of the branchial process in this specimen is transversely striated.

Occurrence of prostomial gill-plumes of Trachyderma.

Melbournian. In buff mudstone, Swanston Street Sewer, near Collins Street (F. P. Spry coll.), hard blue mudstone, Domain Road Sewer, South Yarra (F. P. Spry coll.); blue mudstone, Hawthorn Road Main Drain (F. P. Spry coll.).

Probably Melbournian. Slaty-blue mudstone, four miles north-west of Keilor (A. James coll.). Also tubes of *Trachyderma* with fragments of prostomial impressions (one pectinated), from Silurian mudstone, probably on Warrandyte Anticline at Quarry near Scotchman's Creek, Mulgrave (R. A. Keble coll.).

General Observations on the soft and other parts of Worms found Fossil.—In the Text-book of Zoology, Parker and Haswell,[1] reference is made to the occurrence of Chaetopods in the fossil condition, as follows:—

1 Vol. i., London, 1910, p. 448.

"Owing to the soft character of most of their parts, there are comparatively few actual remains of Chaetopods in the older geological formations, though there are many burrows and tracks which have been ascribed to members of that class. Tubes of tubicolous Polychaeta have, however, been found in formations dating from the Cambrian period onward." Since this was written Cambrian annelids have been described by C. D. Walcott from North America.[1] They belong to the Class Chaetognatha (Amiskwia, Walcott); the class Chaetopoda, sub-class Polychaeta (order *Miskoa*, Walcott); and to the class Gephyrea (Fams. *Ottoidae* and *Pikaidae*, Walcott). These annelids are preserved in their entire form and pressed flat upon the surface of the shale. They are conspicuous in having a shiny film which lies upon a lighter background of shale, and from them Dr. Walcott obtained many remarkable photographs by adjusting the light and carefully re-touching the actual structure seen in the fossil.

The prostomial gills of *Trachyderma* here described are also represented by a dark film, on a lighter grey-shale background, but the fossil remains do not exhibit a sheen, as in the Middle Cambrian examples from British Columbia, above mentioned.

From the Ordovician Shale of Cincinnati, Ohio, Dr. E. O. Ulrich described as far back as 1879[2] some filiform segmented worms, probaly polychaete in affinities, as *Protoscolex*. In the same paper Ulrich figures what is perhaps more interesting from the present standpoint, another form, *Eotrophonia setigera*,[3] which undoubtedly represents prostomial appendages of an annelid.

Those fossils which have been from time to time figured as *Nereites*, as for example, *N. cambrensis*, Murchison,[4] from the Llandeilo of South Wales, I hold to be true impressions of the soft parts of nereid worms, since the lateral serial lobes are exactly similar in form to the parapodia of certain nereid worms like *Phyllodoce*.[5] That they are not due to casual trails of crustaceans, tracks of molluscs, brown seaweeds or other adventitious agencies seems very evident from the sharpness of the impressions, although Nathorst[6]

1 Smithsonian Misc. Coll., vol. lvii, No. 5, 1911. Middle Cambrian Annelids.

2 Journ. Cincinnati Soc. Nat. Hist., vol. i., 1879, pp. 87-91, pl. iv., figs. 1-4. (I am indebted to Dr. Ulrich for a typed copy of this scarce work, with photo-reproductions of the plate).

3 Ibid.. plate iv , figs. 5, 5*a*.

4 Silurian System, pt. ii., 1839, p. 700, pl. xxvii. fig. 1. Siluria, 3rd ed., 1859, p. 220, fossils, p. 221, No. 42(3). Bailey, Char. Brit Foss., 1865, pl. vi., fig. 6.

5 Cf. Cambridge Nat. Hist., vol. ii , 1896. Polychaet Worms. Benham, p. 314, fig. 165.

6 K. Svenska Vet. Akad. Handl., vol. xviii., No. 7, 1881. Also ibid., vol. xxi., No. 14, 1886.

has figured many illustrations of these latter in refutation of some fossils figured as "fucoids," with good reason.

Relationship of Trachyderma to modern forms.—One of the chief determinative characters of these fossil forms in their genetic relationship would probably be the morphology and arrangement of the prostomial gills. These, in the *Trachydermae* now described consist of fairly broad, unilateral, frondescent processes, having a sigmoidal curvature and a well-defined axis. Judging by the appearance of one finely preserved specimen in which the processes lie back to back, they were probably paired. The nearest types of Chaetopods of this character are grouped in the sub-order Sabelliformia.[1] In these forms the branchiae are all more or less distinctly plumed or furnished with secondary filaments, unlike those of the sub-order Terebelliformia, which have simple filose or arborescent processes. The structure of the gills in *Trachyderma* shows many close points of resemblance to *Dasychone*, as in the flattened axis, the secondary pinnules on the inner, concave side of the stem, and especially in the presence of numerous eye-spots and processes known as dorsal appendices.[2] These eyes have been detected on several specimens, so that it is not due to any misinterpretation of the surfaces of the matrix.

The *Sabellidae* form their tubes of mud or sand, or of both, and are usually found in low water as well as to some considerable depths. In the absence of further morphological characters it is advisable to place the Silurian fossil form in a new family, the *Trachydermidae*.

In comparing the recent worms my attention was first drawn to some of the worms of the sub-order Terebelliformia, which also make their tubes of mud or sand. In *Amphitrite johnstoni*, for example, "the gills consist of a curved stem from the convex side of which arise a number of branches, themselves dichotomously divided, the final branches being long,"[3] The pectinate secondary filaments in *Trachyderma*, however, are normally on the concave side of the stem, but occasionally on the outer side when the axis is reflexed. The structure of the axis also agrees more closely with the sabellids, and the vestiges of eyes and dorsal appendices in the fossils are essentially like those of this group.

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1 See Camb. Nat. Hist., vol. ii., 1896. Polychaet Worms. Benham, p. 336.

2 Op. cit., p. 337, fig. 382*b*. Also cf. *Dasychone capensis*. Rep. Chall. Zool., vol. xii., 1885. Annelida Polychaeta, McIntosh, p. 506, pl. liv., fig. i.

3 Camb. Nat. Hist., tom. cit., pp. 328, 329 (fig. 176*a*).

Fam. SERPULIDAE.

Genus **Cornulites**, Schlotheim, 1820.

[*Note.*—This genus is variously regarded as a member of the Annelida or of the Pteropoda. Thus Benham[1] says:—"Many of the tubes referred to Polychaetes by the earlier palaeontologists have been transferred to other groups; thus *Cornulites* is now believed to be a Pteropod shell." In Eastman-Zittel,[2] Dr. G. J. Hinde defines *Cornulites* as "Thick-walled, trumpet-shaped tubes; *Serpula*-like at the lower end, and sometimes attaining a length of three or four inches. Exterior annulated and covered with very fine longitudinal striae. Some authors regard the tubes as Pteropod shells." The genus is there placed, under Chaetopoda, Order Tubicola. The present writer holds that the evidence for the annelid nature of these tubes is quite convincing, since the internal microscopic structure of the shell, as shown by G. R. Vine,[3] is identical in many points with some living tubicolar forms belonging to the family *Serpulidae*, and this is further strengthened by the frequent occurrence of attachment in the earlier stage to foreign bodies.]

Cornulites youngi, sp. nov. (Plate XIII., Fig 4; Plate XIV., Figs. 13, 14.)

Description.—Shell hollow, conical; sides widening moderately rapidly, and expanded at the apertural extremity. Base blunt, subrounded and impressed, as would be the case if attached to a small foreign body. Annulations consisting of a closely set series of well-marked rings projecting from the general surface of the tube, each ring having a sharp, finely tuberculated central ridge or ring, with two lateral ones, sharp and smooth. Longitudinal striae clearly visible, and under a lens, a series of finer, transverse striae between them, somewhat similar to that seen in Vine's *Cornulites scalariformis*.[4] The holotype is practically uncrushed, although in compressed shale, showing the shell was sufficiently thick to withstand the pressure of the sediment as it was thrown down.

Measurements.—Holotype. Length, 24 mm.; greatest width, at apex, 10 mm.; width at middle of shell, 6 mm.; width at 1 mm.

1 Camb. Nat. Hist., vol. ii., 1896, p 302.
2 Vol. i., 2nd ed., 1913, p. 139.
3 Quart. Journ. Geol. Soc., vol. xxxviii., 1882, pp. 379-381, pl. xv., figs. 1, 9, 10.
4 Ibid., pl. xv., fig. 1a.

from base of shell, 3 mm.; about 10 rings to 10 mm. counting from the basis of the shell; 22 rings in total length of shell.

Another, larger, example from the same locality, somewhat badly crushed, has a length of 55 mm. The annulations are about 3 mm. apart in the wider part of the shell. It is probably a senile example of the same species.

Observations.—This species of *Cornulites* is apparently the oldest recorded. The well-known *C. serpularius*, Schlotheim,[1] is a much larger form than ours, and has the distance between the annuli longer. *C. flexuosus*, J. Hall,[2] is closely related to *C. serpularius*, but having a flexuose opex. *C. scalariformis*, G. R. Vine,[3] from the Lower and Upper Wenlock Shales, differs from the Australian species also in having more widely spaced annuli, but the character of the rigid portion of the annulation is in keeping with ours in having a blunted crest, but without a central keel.

The Tasmanian species, *C. tasmanica*, R. Etheridge, junr.,[4] differs in its more quickly tapering shell and decided flexuous habit. The specimens occur as casts in a blue-grey or whitish mudstone from Heazlewood and Zeehan.

Age of the Victorian specimens.—The two examples of *C. youngi* were found in a dark blue slate associated with the remains of the following graptolites:—

Didymograptus caduceus, Salter; *Tetragraptus serra*, Brongn. sp.; *T. quadribrachiatus*, J. Hall sp.; and *Oncograptus* sp.

This assemblage of graptolites points to the lowest part of the Darriwillian stage (4th in the series), of the Lower Ordovician.

Occurrence.—In dark blue slate with cleavage at a low angle to bedding plane. Moorabool River, near Meredith, N.W. of Geelong. Two examples; presented by Mr. James Hay Young, after whom the species is named, in recognition of his valuable assistance in collecting new and rare fossil specimens.

Note on *Pteroconus mirus*, Hinde.[5]

The shell of this generic type recalls *Cornulites*, the chief difference being the "shelly flap or fin-like extensions disposed at regular intervals from the basal point to the summit aperture." There is also a central rod-like structure often present, which, as

1 Schlotheim. Petrefactenkunde, 1820, pl. xxix., fig. 7. Murchison's Silurian System, pt. ii., 1839, p. 627, pl. xxvi., figs. 5-8.

2 Pal. New York, vol. ii., 1851, p. 98, pl. xxviii., figs. 12a-e.

3 Quart. Journ. Geol. Soc., vol. xxxviii., 1882, p. 379, pl. xv., figs. 1. 9, 10.

4 Description of Tasmanian Silurian Fossils presented to the Australian Museum. Hobart. 1896, p. 37, pl. —, figs. 10, 11.

5 Geol. Mag., 1900, p. 149, pl. vii., figs. 1-4. See also Whidborne and Blake, ibid., pp. 239, 240.

Prof. Blake has suggested (loc. cit. p. 240), "may very well be the remains of the intestine filled with matrix." This fossil form is now before me, two fine examples having been given to me on my departure for Australia in 1902, by Mr. Howard Fox, F.G.S., who discovered them, and who then wrote (Dec. 22nd, 1901): "I enclose a specimen of a fossil I have found abundantly at Bedruthan Steps, North Cornwall, and of which Upfield Green the year previous found two specimens on the south coast. *Pteroconus mirus*, Hinde (syn. *Nereitopsis*, Green). If you find any like it at Melbourne send me word. It seems to be a new form. Whidborne calls it *Cornulites*."

My object in writing this note is to draw attention to the corroborative evidence afforded by this related genus that *Cornulites* and *Pteroconus* (or *Nereitopsis*) are tubicolous annelids.[1] In my specimen of *Pteroconus* the basal extremity in each case is expanded, and shows signs of attachment in the larger specimen. *Pteroconus* has not yet been found in the Australian paleozoic sediments.

EXPLANATION OF PLATES.

Plate XIII.

Fig. 1.—*Trachyderma* sp. Part of a prostomial appendage near its termination, showing characteristic sigmoidal curvature of the axis. Silurian. N.W. of Keilor. A. James coll.

Fig. 2.—*Trachyderma* sp. Middle portion of a prostomial appendage, showing plumose character of gills, the striated axis, and vestiges of eye-spots and dorsal appendices. Silurian. N.W. of Keilor. A. James coll.

Fig. 3.—*Trachyderma crassituba*, Chap. A branch near the base of the prostomial appendage. Silurian (Melbournian). Hawthorn Main Drain. F. P. Spry coll.

Fig. 4.—*Cornulites youngi*, sp. nov. Median area of shell, showing ornament of annuli and interspaces. An enlargement of Fig. 13. Lower Ordovician. Moorabool River, near Meredith, N.W. of Geelong. J. H. Young coll.

All the above figures are enlarged 8 diameters.

Plate XIV.

Fig. 5.—*Trachyderma* sp. A narrow tube, widening rapidly to the aperture. It shows some characters pertaining to *T.*

1 Dr. Hinde regarded *Pteroconus* as a Pteropod; the Rev. G. F. Whidborne, as a Cephalopod (Orthoceracone); and Prof J. F. Blake, as a soft-bodied Polychaete.

crassituba, but is not sufficiently well preserved for exact identification. The matrix filling the orifice is stained with an ochreous deposit. To the right there is a fragment of a gill-plume which is like those seen in Fig. 12. Silurian. Probably on Warrandyte anticline, near Scotchman's Creek, Mulgrave. R. A. Keble coll.

Fig. 6.—*Trachyderma* sp. A large sigmoidal appendage, resembling in shape a note of interrogation. Silurian. N.W. of Keilor. A. James coll.

Fig. 7.—*Trachyderma* sp. A number of prostomial appendages on a slab of Silurian mudstone. The arrow points to a sharply bent fragment, from which the sketch showing eye-spots and appendices was obtained (Plate I., fig. 2.) N.W. of Keilor. A. James coll.

Fig. 8.—*Trachyderma crassituba*, Chapman. Some finely pectinated gill-plumes on dense, blue Silurian (Melbournian) mudstone, associated with tubes of this species. South Yarra Sewerage Works. F. P. Spry coll. 19/3/1897.

Fig. 9.—*T. crassituba*. A small sigmoidal appendage. In sandy, ochreous mudstone of a false-bedded character, probably denoting shore conditions. Silurian (Melbournian.) Domain Road Sewer. F. P. Spry coll.

Fig. 10.—*Trachyderma* sp. A curved fragment of a well preserved appendage. Silurian. N.W. of Keilor. A. James coll.

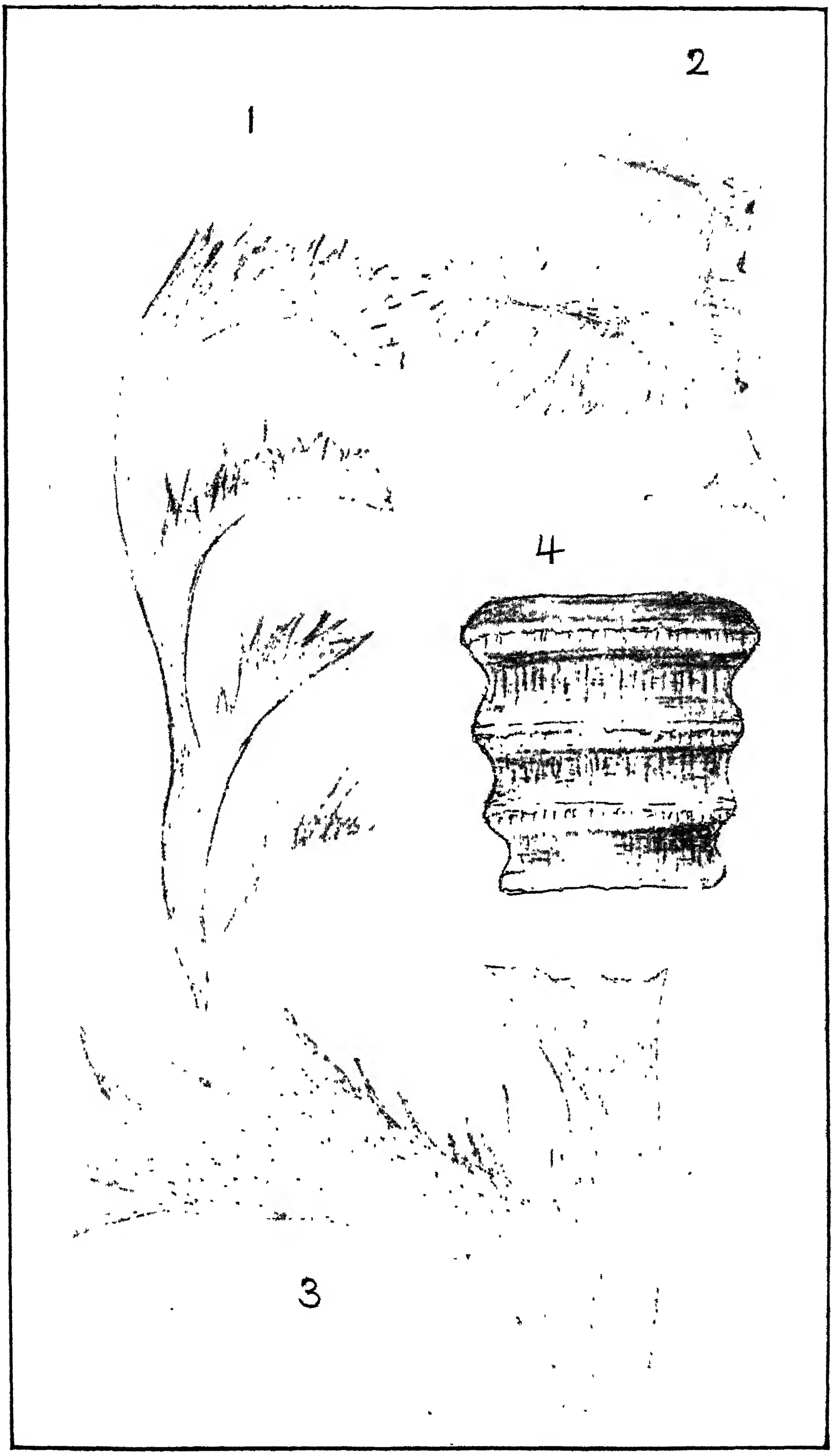
Fig. 11.—*Trachyderma* sp. A well preserved terminal fragment from which Fig. 1 on plate I. was sketched. Silurian. N.W. of Keilor. A. James coll.

Fig. 12.—*Trachyderma crassituba*, Chapm. Two appendages back to back, pointing to their probable paired habit in the living state. Fig. 3 of Plate I. was taken near the base of this specimen. Silurian (Melbournian.) Hawthorn Main Drain, Melbourne. F. P. Spry coll. 1903.

Fig. 13.—*Cornulites youngi*, sp. nov. Shell embedded in Lower Ordovician slate. Moorabool River; near Meredith, N.W. of Geelong. J. H. Young coll.

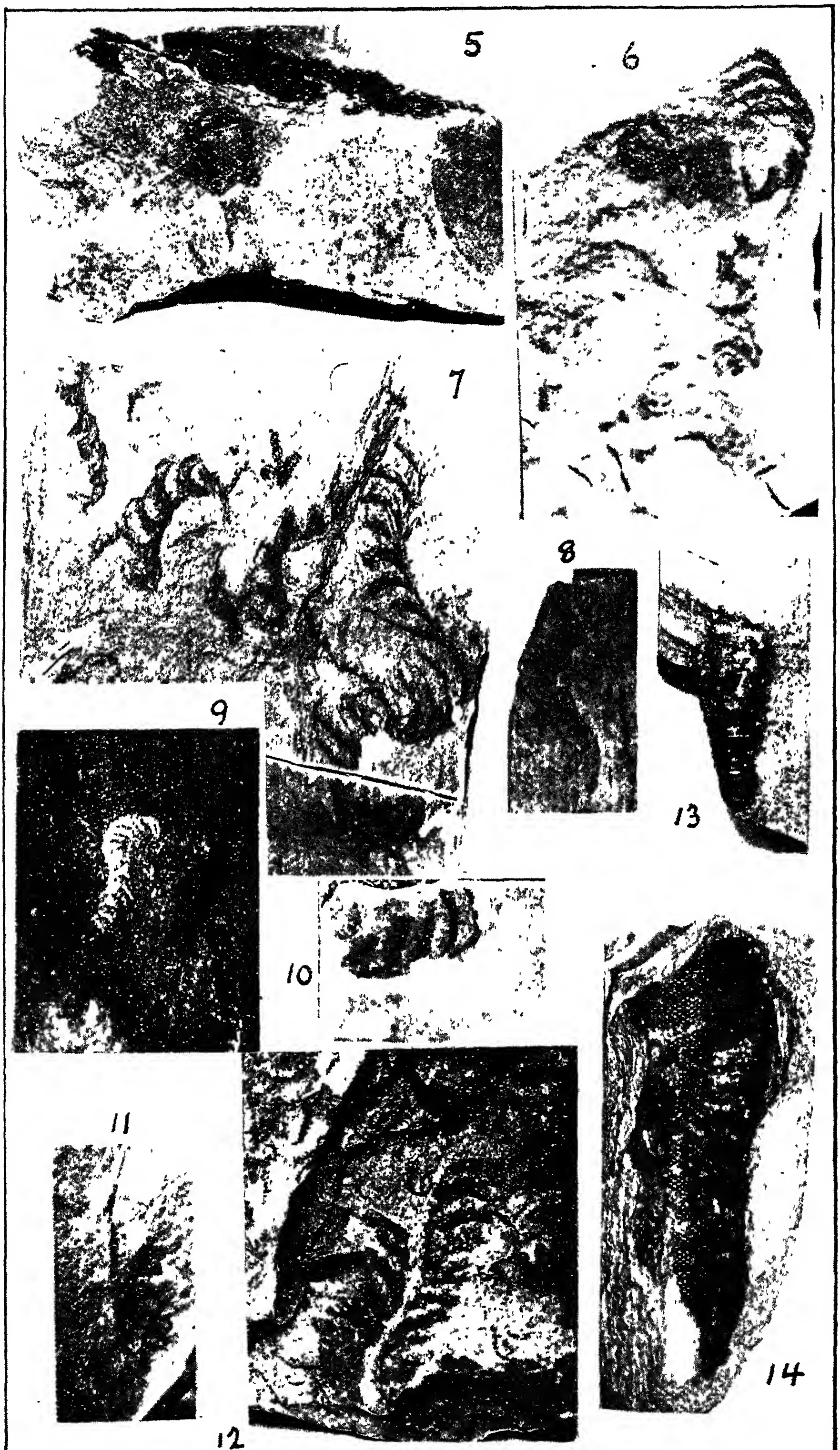
Fig. 14.—*C. youngi*, sp. nov. A senile example, much crushed. Lower Ordovician. Moorabool River, near Meredith, N.W. of Geelong. J. H. Young coll.

All figures on this plate slightly over natural size.



F.C. ad nat. del.

Trachyderma (gill-plumes), and Cornulites, L. Palaeozoic: Victoria.
(× 8).



F.C. Photo

Trachyderma and Cornulites, L. Palaeozoic: Victoria.

(Circ. nat. size).

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919].

Art. XI.—*Abnormal Development of the Head Appendages in the Crayfish, Parachaeraps bicarinatus Gray.*

By JANET W. RAFF, M.Sc.

(Demonstrator in Biology in the University of Melbourne).

(With Plate XV.).

[Read 12th September, 1918].

The specimen described in the following notes is a small male form of *Parachaeraps bicarinatus*—the common yabbie of our pools and streams. It measures 3¼ inches in length, and it shows certain abnormalities regarding the positions of the head appendages. The specimen was handed to me for examination by Dr. Sweet, who thought the irregularities worthy of note.

When viewed from the *dorsal surface* the abnormalities consist of the following points, as shown in Fig. 1:—

(1) The right *eye* appears slightly larger and longer stalked than the left.

(2) The *antennules* are pushed out of position so that both are seen to the right side of the rostrum, the left one being situated above the right.

(3) The exopodites or scaphocerites of the *antennae*, when inclined inwards, are seen to be on a level with the left antennule, and lie one on each side of it. The right one extends slightly more anteriorly than the left. The endopodites of the antennae are on a level with the right antennule.

The head region appears distinctly broader when viewed dorsally than in normal specimens of the same size.

When examined from the *ventral surface* the abnormalities are much more marked (Fig. 2). The most striking point of irregularity lies in the abnormal position of the *mandibles*, the right one being situated at a higher level, i.e., more anteriorly, than the left, it being thus impossible for the two mandibles to bite against one another. The *mandible* of the right side is placed on a level with the *labrum*, instead of posterior to it, and its "teeth" rest against roughnesses on the inner edge of the labrum, which latter is situated entirely on the left side of the head, and *not* in the middle line.

The sternal portion in front of the mouth (*epistoma*) presents a very abnormal appearance. It is practically undeveloped on the

right side, and its anterior limit formed by the *interantennal spine* is inclined over towards the right side.

The *antenna* and the *mandible* are situated much closer to one another on the right side than they are on the left, for not only is the right mandible attached more anteriorly than the left, but also the right antenna is situated more posteriorly than the left. These positions have obviously been taken up owing to the absence of the hard sternal portion on the right side. The *interantennal spine* is broader from side to side, but shorter in length than in a normal specimen, so the distance between the labrum and the tip of the interantennal spine is much shorter than it should be.

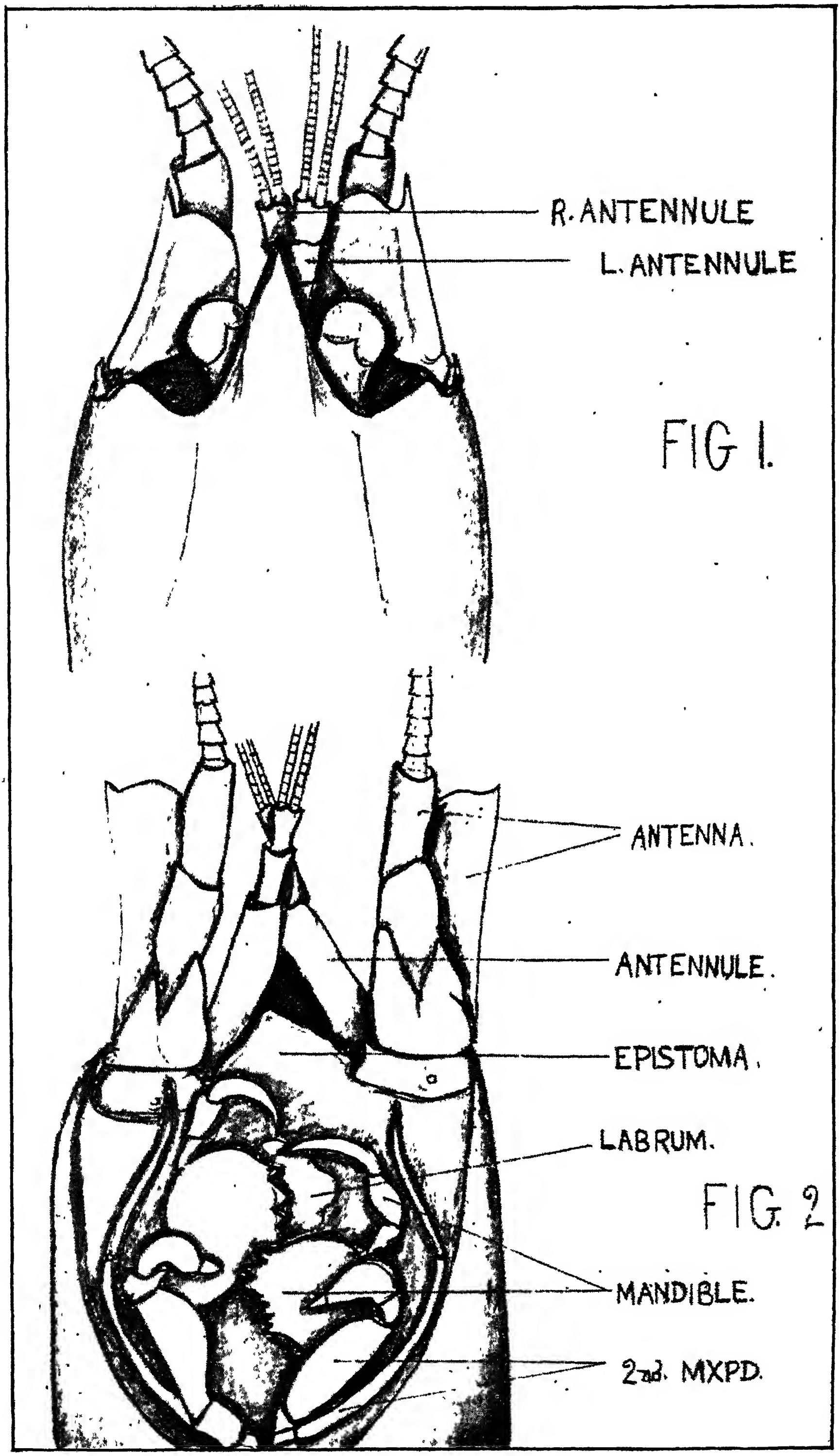
The left *antennule* has apparently become pushed away from its own side by pressure of the antenna against it, due to the shifting over of the epistoma to the right side. This has consequently displaced the right antennule and driven it further back, so instead of lying on a level with the left one, it now appears lower down, i.e., more on a level with the antennae.

All other appendages of the body appear to be quite normal.

EXPLANATION OF PLATE XV.

Fig. 1.—Dorsal view of head of crayfish, showing position of antennules.

Fig. 2.—Ventral view, showing positions of the different parts—the first and second maxillae and the first maxillipede are hidden by the second maxillipede.


R. ANTENNULE
L. ANTENNULE
FIG I.
ANTENNA.
ANTENNULE.
EPISTOMA.
LABRUM.
FIG. 2
MANDIBLE.
2nd. MXPD.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919.]

Art. XII.—*Further Notes on Australian Hydroids—IV.*

By W. M. BALE, F.R.M.S.

(With Plates XVI. and XVII.).

[Read 10th October, 1918].

Silicularia undulata (M. and T.)

Eucopella undulata, Mulder and Trebilcock, Geelong Naturalist (2), vi., 1914, p. 10, pl. ii., figs. 5-7.

Silicularia undulata, Bale, Proc. Roy. Soc. Vict., N.S., xxvii., 1914, p. 89.

I have to thank Mr. R. E. Trebilcock for specimens of this hydroid, stained and mounted in balsam, which have enabled me to examine the structure more satisfactorily than was possible with my specimens of *S. campanularia*, in which the hydranths were partly retracted, and blackened to almost complete opacity. In Mr. Trebilcock's specimens the hydranths were widely expanded, rendering the investigation of their structure comparatively easy.

The hydrothecae are similar to those of *S. campanularia*, and the lateral inflations of the hydranths are obvious; these, however, are not in any way to be regarded as distinct structures, the condition simply being that the body is "lop-sided," the inflated side occupying the space over the lower lip of the hydrotheca, while the distal portion of the hydranth leans over the opposite lip. The peduncles are spirally undulated, like those of *Orthopyxis caliculata*, and they are gradually enlarged at their junction with the hydrotheca, in marked contrast to those of *S. campanularia*, which have their thick walls narrowed in at the corresponding points. It is interesting to note the parallelism in regard to the peduncles of *Orthopyxis* and *Silicularia*, the massive thick-walled straight peduncles of *S. campanularia* having their counterparts in *O. compressa* and *O. angulata*, while the thin wavy stalks of *S. undulata* correspond similarly with those of *O. caliculata* and other species.

The point of most interest is the structure of the oral region, especially as this proves identical in its main features with that of *Orthopyxis caliculata*, and also with that of *Campanularia grandis* Allman, the latter of which has been made by Broch the type of a new family—the Bonneviellidae.

The salient character is in the origin of the proboscis, which is derived from the tentacles. These are united in the proximal portions, so as to form a calyx, lined by an endodermal layer, which extends to its margin, at which part the tentacles become free. From the edge of the calyx springs the proboscis, which is normally dome-shaped, with a small central aperture, but which, when the hydranths are fully expanded, stands erect and open, like the corona of a Narcissus. This corona is seen in optical section to consist of a mesosarc branching off from the united mesosarcs of the tentacular calyx, with, outside it, a thin pellicle of ectoderm, and inside a thick layer, presumably endodermal, which continues downward uninterruptedly into the layer of similar tissue which lines the calyx. As usual in the order, this tissue is denser and closer than the endoderm in the lower part of the body; it forms a layer with a well-defined inner boundary, and is uniform in thickness for most of its extent, but becomes thicker opposite the extreme bases of the tentacles, below which it gradually passes over into the ordinary endoderm of the body cavity.

The difference between this type of hydranth and that of a typical Campanularian, such as *Obelia*, is very marked. In *Obelia* it is true the basal portions of the tentacles are adherent, forming a calyx, but this is composed of the tentacles alone, which are borne on the hydranth quite apart from the large mobile proboscis, which they surround at some distance. In *Silicularia*, on the other hand, we have a hypostome of which the lower half is composed of the tentacular calyx, with its cellular lining, while the upper half (proboscis), is a free extension of this same calyx. The structure may probably be explained on the assumption that the ordinary proboscis has been modified by its proximal portion becoming completely adherent to the tentacular calyx (forming its lining), while the upper part remains free and retains its mobility.

The proboscis, or free portion of the hypostome, is encircled by a band of irregular rounded or convoluted masses of a special granular tissue, which project from its outer surface with a thickness about equal to that of the proboscis-wall itself. Their function is not obvious.

The hydranth-body is roughly globular, with a distinct salient angle which fits into a small sinuation in the hydrotheca. Its diameter, from the base to the root of the tentacles, averages about .22 mm., and the distance thence to the edge of the proboscis is about .15 mm. The proboscis, when erect, is about .20 across.

There are usually about 22 tentacles, which, fully expanded, reach about .60 mm. in length.

In my specimens of *S. campanularia* the proboscis, which I have described as an annular band bordering the calyx, is narrower than in the present species, and it is spread outward nearly horizontally; in those specimens, however, the tentacles are mostly reverted, besides being contracted, and I have had no opportunity of observing well-preserved specimens.

Note on the relationships of SILICULARIA, ORTHOPYXIS and BONNEVIELLA.

In the last paper of this series I have referred to the "annular band" of *Silicularia* as the homologue of the proboscis of *Orthopyxis;* the study of *S. undulata*, however, and comparison with several species of *Orthopyxis*, has satisfied me that the two genera are, in regard to the form of the hypostome, really identical in structure. The specimens of *Orthopyxis* which were most favourable for examination belonged to the form which I have called *O. angulata*, but I was able to satisfy myself that other species, including *O. caliculata*, were of the same type, the hypostome being formed, in its lower half, by the tentacular calyx, with its cellular lining, and in the upper half by the free extension or outgrowth of the same, which constitutes the proboscis. Whether the external band of granular material which I have noticed as encircling the proboscis in *S. undulata* is present in *Orthopyxis* was, however, not discernible in the specimens, which were by no means in so favourable a condition for examination as the *Silicularia*.

That so well known a species as *O. caliculata* should prove so different in the character of its hypostome from the other forms (such as *Obelia*) with which systematists generally class it, was an unexpected result, as even Agassiz, in his study of this species, states that the structural elements are the same as those of most campanularians (including *Obelia*). On referring, however, to Jickeli's second paper on "Der Bau der Hydroidpolypen," which contains a careful study of *C. caliculata*, I find the remark "Der Raum zwischen Hypostom und Armen ist hier so reducirt das auf Langsschnitten die Wandung des ersteren nur wie eine Abzweigung der letzteren erscheint." This might seem to imply merely a close approximation between the hypostome and the tentacles; the figure of a longitudinal section shows distinctly, however, the mesosarc of the proboscis springing directly from that of the tentacles, and

agrees perfectly with the foregoing account of *S. undulata*. It is to be noted that Jickeli describes the lining of the hypostome as endodermal.

In 1909[1] Broch established the genus *Bonneviella* and the family BONNEVIELLIDAE for the *Campanularia grandis* of Allman, on characters which, he claimed, distinguish it sharply from all other Campanularians. These characters, however, are mainly those which Jickeli had already shown to exist in *C. caliculata*, with this exception, that the distal cavity which is enclosed above by the proboscis or corona (which he calls the *veloid*), is lined by ectoderm instead of endoderm, and is regarded by him as a pre-oral cavity, not as a hypostome. He says:—"The greatest difference from all other hydroids is found in the mouth-part of the hydranths. Right on the place of union of the tentacles, and on their inner side, is found a velum-like lamella, the "veloid." This veloid is extended like a disc over the whole mouth-part of the hydranths, and has only a small centrally situated hole through which admission is obtained to a pre-oral cavity. The veloid is composed of two ectodermal cell-layers, which are divided by a membrane, this membrane apparently springs directly from the stütz-membrane of the tentacles, and must be considered as a continuation of the same. Inside the veloid the ectoderm is continued as a single-layered cylinder-epithelium which, however, passes over into a cylinder-epithelium of several layers towards the bases of the tentacles. The transition from ectoderm to endoderm is found at the under side of the tentacle-bases, so that an ectodermal food-passage seems to be formed; whether, however, this is caused by the contraction of the hydranth I do not venture to decide with certainty.

Fam. BONNEVIELLIDAE.

"Thecate Hydroida provided with a veloid, so that a pre-oral cavity is constituted. The single known genus

BONNEVIELLA, nov. gen.

"Trophosome. Hydranth with a single series of tentacles which are united together as far as the veloid. Ectoderm-lined food-passage.(?) Hydrothecae bell-shaped, with thin diaphragm. Erect colonies which spring from a rhizocaulon.

"Gonosome. Gonangia dispersed over the stem. Gonophores sessile. Colonies sexually distinct."

1 Nyt Magazin f. Naturvidensk, B. 47, 19 9, p. 195, fig. 1.

From the foregoing account, and from Broch's figure, it is obvious that in the most important feature—the form of the oral portion of the hydranth—the species described agrees absolutely with *Silicularia undulata* and *Orthopyxis caliculata*, as I have described them, and also with Jickeli's figure of the latter species. The likeness is emphasized in the description of *B. regia* by Nutting, who says that the "veloid" is dome-shaped, in which it agrees with the proboscis of the above-mentioned two species when not expanded.

We have therefore in *Bonneviella* and *Orthopyxis* precisely the same structure of the oral region, except that in the one case the proboscidial cavity is said to be lined with ectoderm, while in the other the lining membrane is described as endodermal ; a difference which could hardly be demonstrated in the absence of sections. For it is recognized that in the ordinary Campanularian hydranth the hypostome is lined with a special endoderm, consisting of cylinder-cells smaller and with smaller nuclei than those of the main body-cavity (probably implying special functions), while Broch describes the ectodermal lining of the distal cavity in *Bonneviella* as also consisting of cylinder-epithelium. The thickening of the lining membrane opposite the bases of the tentacles is equally noticeable in *Bonneviella* and in *Silicularia*.

I have seen no sections, but on the authority of Jickeli I regard the proboscidial cavity of *Orthopyxis* as a true endoderm-lined hypostome, and the very close affinity existing between that genus and *Silicularia* seems to justify the ascription of the same character to the latter. The outstanding difference between the hydranths of these two genera is the unilateral inflation in *Silicularia*, which is correlated with the remarkable form of the hydrothecae.

A peculiarity of *Bonneviella* is the structure of the endoderm of the tentacles, the cells being in several series, a feature which Broch says is not found elsewhere among the Thecaphora.[1]

Note on the name ORTHOPYXIS.

Dr. Fraser, in a recently-published paper,[2] advocates the use of the name *Eucopella* in preference to *Orthopyxis*, on the ground that Agassiz failed to indicate the special characters which induced him to separate *O. caliculata* from other Campanularians. I do

1 It may be noted that Stechow does not accept Broch's interpretation of the oral structure in *Bonneviella*, but considers that the figure indicates the existence of a conical hypostome, such as characterises the Lafoeidae.—Hydroidpolypen der japanischen Ostküste, ii., 1913, p. 28.

2 Hydroids of Eastern Canada. Ottawa, 1918.

not think, however, that it is the practice of zoologists to reject a proposed genus or sub-genus merely because a formal diagnosis is wanting, when, as in this instance, a full description is supplied. The case is exactly parallel with that of *Ectopleura*, which also was established by Agassiz without a formal diagnosis. Allman complained that Agassiz had not definitely stated the points on which he founded the genus, but nevertheless, considering it valid, he unhesitatingly accepted Agassiz' name for it. Both Professor Nutting and Dr. Stechow agreed that *Eucopella* should be cancelled in favour of Orthopyxis.

The fact, cited by Fraser, that Hincks did not accept Agassiz' name, does not bear upon the question. Hincks did not accept the genus itself as distinct from *Campanularia;* had he done so it is not conceivable that he would have rejected the name. I cannot agree with Fraser's statement that we "do not know, and never can know, that Agassiz had any such characters [as those of *Eucopella*] in mind when he applied the subgeneric name *Orthopyxis* to his species *poterium.*" Agassiz states expressly that he finds nothing in the trophosome to distinguish *Orthopyxis* from other Campanularians; we know, therefore, that his separation of it depends solely on the peculiar structure of the reproductive zooid, which is precisely the character on which *Eucopella* was established.

SACCULINA, n. gen.

——— n. gen. Bale., Proc. Roy. Soc. Vict., vi. (N.S.), 1893, p. 96.

?*Tibiana*, Lamarck, in part, An. s. Vert., ii., 1816, p. 149.

Hydrophyton an erect tube of irregular form; zooids produced from short tubular processes, which are borne on inflated areas on all sides of the hydrocaulus. Hydranths and gonozooids unknown.

The single species for which this genus is established, though so imperfectly known that we are quite in the dark as to its affinities, is readily identifiable, and as I have already published an account of it, but without name, and as it cannot be assigned to any known genus, I now propose for it the name *Sacculina*. This name is borrowed from Lamarck, who states that he at first intended applying it to the zoophyte (apparently very closely allied to the present species), for which he ultimately decided upon the name *Tibiana ramosa*.

Full particulars will be found under the specific description.

SACCULINA ARENOSA, n. sp.

——— ———, n. gen. et sp.?, Bale, Proc. Roy. Soc. Vict., vi. (N.S.), 1893, p 96, pl. iii., figs. 1, 2.

??*Tibiana ramosa*, Lamarck, An. s. Vert., ii., 1816, p. 149. Lamouroux, Hist. Polyp. Cor. Flex., 1816, p. 219. Schweigger, Beobacht. auf. naturh. Reisen, 1819, pl. vi., fig. 56.

This curious zoophyte, which was described by me in 1893, but not named, is so distinctive in character that there seems to be little doubt as to the propriety of assigning it to a separate genus, even though it is so imperfectly known that we are entirely ignorant regarding its position. In many respects it agrees with the *Tibiana ramosa* of Lamarck, an insufficiently described species not known to later observers.

The hydrocaulus consists of string-like stems, sometimes with a few ascending branches, which may be given off in a cluster, eight or nine inches, or perhaps more, in height, monosiphonic and not distinctly jointed; it differs markedly from the ordinary monosiphonic stem in the singular irregularity of its form, due to the presence of numerous swellings on all sides from which the polyp-tubes originate, and its strangely bent and contorted state in parts, especially near the summit. Its perisarc has a cartilaginous appearance, is of tough consistence, between dirty whitish and light brown in colour, and in the older portions very thick but not opaque; the surface showing innumerable markings such as irregular striations and wrinklings, with round spots somewhat resembling oil-globules.

The polyp-tubes are very narrow in proportion to the diameter of the hydrocaulus, springing from all sides and without regular order; those on the older portions of the polypary are mostly directed upwards from the stem-protuberances, from which they are not separated by any partition or constriction; while in the distal region, where there is the greatest irregularity of the stem, they are often more distinctly defined and more variable in their direction. In many of the older ones the central channel is not more than one-third of their total diameter. Some of these little tubes are short, their length about equalling their width, but more commonly they are two or three times as long. Close to the end they have an annular thickening, darker in colour than any other part of the perisarc, outside which the margin is quite sharp, often slightly ragged. Regenerations

are frequent, including two to four tubes in succession, and I have seen an instance where the regenerated tube was bifurcated. In several instances I observed just within the margin the remains of what seemed to be a septum with a small central aperture. In many portions of the polypary the central thread of coenosarc, or rather its disintegrated remains, persisted, with branches running off to the polyp-tubes; nowhere, however, were any hydranths to be found, nor any remnants of them, nor were any hydrothecae present.

In some instances the tubes bore small collapsed membranous-looking capsules, which seemed to be the earliest stages of the gonothecae. Two or three capsules were observed in a more advanced condition; these were about 1.2 mm. in length, of a compressed ovate form, and much resembling the male gonangia of *Halecium gracile;* they contained the remains of the zooids. On making a more extended examination of the material than I had previously done, in the hope of discovering the hydranths, I found several much larger receptacles, presumably adult gonangia. They were elliptic sacs of about 4-5 mm. in length, formed of an extremely thin, colourless perisarc, and having the whole external surface coated with grains of sand, Foraminifera, and calcareous fragments. These were firmly adherent, and on forcible removal with a needle left their impression on the perisarc. The capsules appeared empty, so far as could be observed through the interstices of the sand-grains, but no apertures were visible; it is quite possible, however, that ruptures might be present, but not traceable owing to the investment of foreign matters.

According to the descriptions of Lamarck and Lamouroux, the *Tibiana ramosa* of the former author would seem to be a form much resembling the present, but with the polyp-tubes less developed. In *Tibiana*, Lamarck comprised zoophytes presumably allied to *Tubularia*, but with the polyps borne laterally along the stem and branches instead of terminally. *T. fasciculata*, the type-species, has often been figured; it is acutely zig-zagged, with an aperture at each angle; it has not been identified, and is probably not a Hydroid. *T. ramosa*, according to Lamouroux, is most likely not a *Tibiana*, and, in fact, there is no reason to assume any relationship between the two species.

Schweigger has figured *T. ramosa*, but very crudely; the figure, however, shows all the irregularity which characterises the present species; some of the polyp-apertures seem merely holes in the perisarc, while others are situated in distinct protuberances. On

the whole, judging from the figure and the descriptions, the most that can be said is that they may just possibly be intended for the species before us.

The specimens of both species of *Tibiana* were said to be in the Museum d'histoire naturelle, but Billard does not refer to them in his revision of the Lamarck collection. *T. ramosa* is said to inhabit the seas of New Holland.

Eudendrium generale von Lendenfeld.

Eudendrium generalis, v. Lend., Proc. Lin. Soc. N.S.W., ix., 1884, p. 351, pl. vi. Kirkpatrick, Sci. Proc. Roy. Dubl. Soc., vi. (N.S.), 1890, p. 607, pl. xv., figs. 1-2.

Eudendrium generale, v. Lend., Proc. Lin. Soc. N.S.W., ix., 1884, p. 621.

Hydrosoma about 3 inches in height, stem fascicled at base, branched and re-branched pinnately, branches ascending, alternate, rather distant, both series borne towards the front; branches and branchlets irregularly annulated for a short distance above their origin, and occasionally elsewhere.

Hydranths large, with about 18-20 tentacles, 4-6 clusters of nematocysts forming a circlet a little above the base.

Female gonophores about .4 mm. in diameter, 3-6 on a hydranth, crowned with a convex cap of nematocysts. Male gonophores moniliform, borne in verticils on the base of a hydranth. Hydranths which bear gonophores often more or less atrophied.

Specimens of this hydroid were dredged in Port Phillip by the late Mr. J. Bracebridge Wilson. Von Lendenfeld's figure shows four female gonophores (called by him the male) of equal size and symmetrically arranged around a hydranth; in my specimens there are from three to six, of varying size according to the order of development.

To the accounts of von Lendenfeld and Kirkpatrick it may be added that each hydranth is provided with about four to six small pads or cushions consisting of clusters of thread-cells, and that most of the female gonophores are surmounted by a cushion of the same kind, but usually larger, from which stream out tufts of filaments about 1 mm. in length, and slightly thickened at the ends. In *E. arbuscula* and *E. capillare* similar structures are found on the *male* gonophores.

Ophiodes australis, n. sp. (Plate XVI., Fig. 1).

Hydrorhiza a network of stout tubes, becoming more or less fascicled; stem straight, polysiphonic, between one and two inches in height, branches short, straight, monosiphonic, divided into internodes by straight or very slightly oblique joints; each internode supporting a hydrophore close to the top.

Hydrophores (primary) alternate, seated on very short processes of the internodes, long, normally divided by a slight constriction into two parts—a proximal, which is cylindrical, and a distal, which is slightly expanding, with a narrow limbus and a circlet of bright points. Secondary hydrophores when present given off laterally from the proximal portion of the primary one, a third and fourth sometimes present, each springing in the same way from its predecessor.

Sarcothecae small vase-shaped cups, springing from the sides of the primary hydrophores, or sometimes of the others.

Hydranths stout, constricted below the crown, with about 24-26 tentacles.

Gonangia barrel-shaped or nearly cylindrical above, tapering below; summit broad and flat; borne on the hydrorhiza.

Loc.—Port Phillip Heads (Mr. J. Bracebridge Wilson), Green Point, Port Jackson (Australian Museum).

The stems originate as small monosiphonic shoots, bearing hydrophores, but soon become polysiphonic by the addition of supplementary tubes which grow upwards from the hydrorhiza; sometimes also these tubes run for a short distance along the proximal parts of the branches. The latter may spring from the supplementary as well as from the primary stem-tubes.

In some cases the hydranths may be single, but more commonly they are borne two by two, each primary hydrophore giving origin to a secondary one from the side near the base, and both supporting hydranths at the same time. Less often three and four may be produced, each from the preceding one; this occurred on the older parts of a shoot. The hydrophores themselves are of the type usual in the family, but I saw no instance of the regeneration-growth so characteristic of most of the species.

Sarcothecae were not numerous, and did not occur with any regularity, most of the hydrophores not being provided with them.

SERTULARELLA RENTONI Bartlett. (Plate XVI., Fig. 2).

Sertularella rentoni, Bartlett, Geel. Nat. (2), iii., 1907, p. 43, fig. —. Mulder and Trebilcock, Geel. Nat. (2), vi., 1914, p. 9, pl. i., fig. 4, pl. iii., fig. 1.

Hydrocaulus simple or pinnate, twisted at the base, about 6 mm. in height, divided by slender twisted joints into internodes, each bearing a hydrotheca about the middle or slightly above.

Hydrothecae tubular or sub-conical, adnate a little less than half their length, widely divergent and nearly in one plane, aperture not contracted, margin with three teeth, one superior and two lateral; no internal teeth.

Gonothecae springing from the base of the hydrocaulus, large, sub-globular, smooth; a short conical neck rising from within a slight depression at the summit, aperture small, entire.

Loc.—Queenscliff; Bream Creek; (Bartlett).

The trophosome of this species so closely resembles that of *S. pygmaea* that it would be no easy matter to distinguish between them with certainty in the absence of the gonangia, which, however, are entirely unlike, those of *S. pygmaea* being of the annulated type characteristic of *S. Johnstoni*. The hydrothecae of the present species seem to average slightly longer than those of *S. pygmaea*, in other respects, including the presence in many cases of a membranous oblique septum, they are alike, as are the angular strongly twisted internodes.

S. unilateralis (Lamouroux)[1] is like *S. rentoni* in the gonangia as well as in the trophosome, and seems to be distinguishable mainly by the presence of internal teeth in the hydrotheca.

SERTULARELLA DIAPHANA Allman. (Plate XVI., Fig. 5).

?*Sertularia tridentata*, Lamouroux, Hist. Polyp. Cor. Flex., 1816, p. 187.

Thuiaria diaphana (Busk. M.S.), Allman, Journ. Linn. Soc. Zool., xix., 1885, p. 145, pl. xviii., figs. 1-3.

Thuiaria hyalina, Allman, "Challenger" Hydroida, Pt. II., 1888, p. 69, pl. xxxiii., figs. 2-2a.

Sertularella lata, Nutting, Amer. Sert., 1904, p. 85, pl. xviii., fig. 10; Idem, Bull. U.S. Fish Comm., 1905, p. 948. Billard, Arch. de Zool. exp. et gén. (4), vii., 1907, p. 346, fig. 4.

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1 Billard, Ann. Sci. Nat. (9), ix., 1909, p. 315, figs. 3, 4.

Sertularella Torreyi, Nutting, Bull. U.S. Fish Comm., 1905, p. 949, pl. iv., fig. 4; pl. xi., figs. 2, 3.

Sertularella speciosa, Congdon, Proc. Amer. Acad. of Arts and Sci., xlii., 1907, p. 476, figs. 24-28.

Sertularella tridentata, Billard, Ann. Sci. Nat., Zool. (9), ix., 1909, p. 312; xi., 1910, p. 14. Stechow, Hydroid-polypen der jap. Ostküste, II., 1913, p. 137, figs. 111-113; (No. 17 Thuiaria sp., Inaba, Zool. Mag. Tokyo, 1890, figs. 46-48). Bale, "Endeavour" Report, Part III., 1915, p. 288.

In the "Endeavour" Report I have referred to this species (under the name of *S. tridentata*) when dealing with *S. lata*, which had been confused with it, pointing out that the two species agree so closely as to be easily mistaken for one another in the absence of the gonosome. I had not then seen the species described by Billard as *S. tridentata*, but have since, through the kindness of my friend, Mr. James Wilson, been furnished with fertile specimens collected by the Rev. Dr. Porter at Moreton Bay, from which locality Busk's specimens, described by Allman as *Thuiaria diaphana*, were also obtained.

In the above-cited paper are enumerated the main differences between the gonangia (which indeed are dissimilar in every particular), and I will only add that those of *S. lata* are very large (about 3.5 mm. in length), while those of the present species are smaller, more delicate, and hyaline. They are not so symmetrical as might be expected from the published figures, but apt to be rather irregular, with the longitudinal plications sometimes distinct, but often faintly marked, and in some cases entirely wanting.

But apart from the gonangia I found no difficulty in distinguishing the two species. It is true that many of the hydrothecae intergrade, but on comparing typical specimens, and especially the proximal portions of the pinnae, we find that in *S. lata* the hydrothecae are closer together, are less divergent laterally, and not turned so much to the front, and that the apertures are more nearly vertical. In all cases the figures cited in the list of synonyms agree in these particulars with the form before us rather than with *S. lata*. The differences are doubtless no more than might reasonably be expected to occur within the limits of a species, and observers meeting with infertile specimens would naturally associate them together. I have probably done this in regard to certain specimens from Port Stephens, which I considered

as a varietal form of *S. lata;* these agree so completely with my present specimens that I have now little doubt that they really belong to the same species. Of course if it should be found that the trophosomes of either or both species intergrade so far as to bridge the slight gap between them it will have to be recognised that certain identification will be possible only in the presence of the gonangia.

Whether the species before us is really the *S. tridentata* of Lamouroux is doubtful. The figure published by Billard in 1907 as S. *lata* undoubtedly belongs to the present species, but unfortunately Billard did not give a figure of Lamouroux' specimen in his revision of that author's collection; he mentions, however, that the hydrothecae were as closely set as in my figure of *S. lata*, a character which would tend to indicate that Lamouroux' specimens may belong to the true *S. lata*, or else that they may be, as to the trophosome, intermediate. If they are not sufficiently distinctive to be referred with certainty (the gonosome being absent) to either form they should be ignored; in any case unless they can be clearly identified with the present species the name of *S. diaphana* (Allman) must remain.

I follow Billard in associating *S. Torreyi* Nutting with his "*S. tridentata*," and I find nothing to distinguish *S. speciosa* Congdon from Nutting's species. *T. diaphana* Allman has also been associated with these by Billard, in this case after examining the original type. The gonangia were observed in all these forms. Allman's types of *T. hyalina*, in which the gonosome was wanting, have been examined by Billard and also by Nutting, who both considered the species the same as the present. Neither of these observers refers to the hydranths of *T. hyalina*, regarding which Allman says that the hydranth is quite unable, even when most fully retracted, to withdraw the tentacular crown into the hydrotheca, and that notwithstanding the complete development of the latter the hydranths derive almost as little protection from them as those of *Halecium* do from the hydrothecae in that genus. This description is not applicable to *S. lata*, as I have a specimen including the hydranths, which are fully retracted into the hydrothecae, and with ample space to spare. Congdon has observed the hydranths in his *S. speciosa*, and has figured them expanded, but says nothing as to their retractility.

SERTULARIA MINUSCULA Bale, nom. nov.

Sertularia minima, Thompson, var. tubatheca, Mulder and Trebilcock, Geel. Nat. (2), vi., 1914, p. 40, pl. iv., figs. 1-1d.

Sertularia pusilla, Bale, "Endeavour" Rept., Pt. iii., 1915, p. 271, pl. xlvi., figs. 3-6.

Not *S. tubitheca*, Allman, Mem. Mus. Comp. Zool. Harv., v., 1877, p. 24, pl. xvi,. figs. 5-6.

Not *S. pusilla*, Thornley, Willey's Zool. Results, Pt. IV., 1900, p. 455.

In naming this hydroid *S. pusilla*, I overlooked the fact that Miss Thornely had already applied that name to another species; the above name is therefore substituted.

SERTULARIA MCCALLUMI Bartlett. (Plate XVI., Figs. 3-4).

Sertularella McCallumi, Bartlett, Geel. Nat. (2), iii., 1907, p. 62, fig. —. Mulder and Trebilcock, Geel. Nat. (2), vi., 1914, p. 7, pl. i., figs. 1-3.

Hydrocaulus simple, divided by oblique joints into short internodes, each bearing a hydrotheca about the middle, internodes with a septal ridge.

Hydrothecae long, conical, smooth, adnate for about one-third of their length, all springing from the front of the hydrocaulus but widely divergent alternately to right and left, aperture slightly expanding, with two large rounded lateral teeth or lobes.

Gonothecae ?

Loc.—Queenscliff; Bream Creek; (Bartlett).

In this curious species the hydrothecae are borne so much to the front as to recall (in side view) the arrangement in *Hydrallmania*, an appearance which is emphasised by the closeness of the hydrothecae, owing to the shortness of the internodes. The latter, separated by very oblique nodes, have a transverse fold at the back, accompanied by an internal ridge, less oblique than the nodes. The aperture of the hydrothecae resembles that of *S. macrocarpa*, and as in that species the adcauline wall is thickened up to the margin, which is firm and smoothly outlined.

In habit the species much resembles *Sertularella secunda* Kirchenpauer, which, however, differs in having a tridentate aperture, as in *S. Johnstoni*. According to Levinsen's system, *S. McCallumi* would be ranked under the genus *Odontotheca*.

PLUMULARIA FILICAULIS Poeppig.

Plumularia filicaulis, Poeppig, Kirch., Abh. Nat. Ver. Hamb., vi., 1876, p. 47, pl. v., fig. 6. Bale, Cat. Aust. Hyd. Zooph., 1884, p. 134, pl. xi., figs. 6, 7, pl. xix., figs. 41, 42. Idem, Proc. Roy. Soc. Vict. (N.S.), vi., 1893, p. 115. Idem, "Endeavour" Report, iii., 1915, pp. 293, 295. Nutting, Amer. Plum., 1900, pp. 60, 76, pl. ii., fig. 6. Hartlaub, Zool. Jahrb., Suppl. vi., 1905, iii., p. 682, fig. M5. Mulder and Trebilcock, Geelong Nat. (2), iv., 1909, p. 34. Idem, Geel. Nat. (2), vi., 1915, p. 52. Idem, Geel. Nat. (2), vi., 1916, p. 80, pl. x., figs. 6a, 6b, pl. xi., figs. 3, 3a.

Plumularia lucerna, Mulder and Trebilcock, Geel. Nat. (2), iv., 1911, p. 122, pl. iii., fig. 4. Idem, Geel. Nat. (2), vi., 1915, p. 52.

Antennella filicaulis, Bedot, Rev. Suisse de Zool., xxv., 1917, pp. 111-124.

Experience has shown that it is quite usual in this species for pinnate stems and simple hydrocladia to spring from the same hydrorhiza; the var. *indivisa*, therefore, which I formerly proposed, cannot be maintained.

In a colony which was growing on Laminaria I found that from certain points the hydrorhiza radiated in four directions at right angles to each other. From the central point sprang a pinnate shoot, while the shoots which originated from other parts of the hydrorhiza were usually (but not invariably) simple hydrocladia.

An interesting feature is the thin and delicate condition of the lateral sarcothecae, a character which is no doubt correlated with their protected situation partly behind the lateral webs which join the hydrotheca to the hydrocladium. Not only is the sarcotheca-wall thin and towards the base even flaccid, but the septum which in sarcothecae of this type usually divides the cavity into two loculi, is in most cases quite obsolete, so that the sarcotheca is practically monothalamic. But here and there one finds a sarcotheca in which the septum persists in a vestigial condition, being reduced to a very slight annular ridge.

The delicate nature of the lateral sarcothecae no doubt renders them very liable to detachment, and so accounts for the occasional occurrence of specimens in which these appendages are entirely wanting.

In a paper by Bedot, just to hand, the species is referred to the genus *Antennella*.

PLUMULARIA SCABRA Lamarck. (Plate XVII., Figs. 4-5).

Plumularia scabra, Lamarck, An. s. Vert., 1816, p. 127. Blainville, Man. d'Act., 1834-7, p. 478. Bale, Cat. Aust Hydr. Zooph., 1884, p. 145. Billard, Ann. Sci. Nat. (9), v., 1907, p. 322. Idem, Ann. Sci. Nat. (9), xi., 1910, p. 36. Idem, Siboga-Exp. i., Plum., 1913, p. 47.

Plumularia effusa, Busk, Voy. of Rattlesn., i., 1852, p. 400. Kirchenpauer, Abh. Nat. Ver. Hamb., vi, 1876, p. 46, pls. i., v., figs. 4, 4b. Bale, Cat. Aust. Hyd. Zooph., 1884, p 129, pl. xviii., fig. 5. Idem, Trans. and Proc. Roy, Soc. Vict., xxiii., 1887, p. 94.

Acanthella effusa, Allman, Rept. Chall. Plum., 1883, p. 27, pl. vi., figs. 1-4. Marktanner-Turneretscher, Ann. k.k. naturh. Hofmuseums, v., 1890, p. 260. Kirkpatrick, Sci. Proc. Roy. Dublin Soc., vi. (N.S.), 1890, p. 610, pl. xiv., fig. 4. Campenhausen, Abh. d. Senckenb. naturf. Gesellsch. Frankfurt-a-M., xxiii., 1897, p. 315.

I have been favoured by Dr. Kirkpatrick with fragments of both Busk's and Allman's specimens of this species, which I had not previously seen. It is very closely allied to *P. badia* Kirchenpauer (*P. Ramsayi* Bale), and some of the points of contrast between them to which I referred in the "Catalogue" do not exist, but were due to errors in Kirchenpauer's figures and description. The hydrocladia in *P. scabra* are borne on stout bracket-like apophyses exactly as in *P. badia*, but in all the specimens which I have seen they spring more from the front of the hydrocaulus (a feature also noted by Kirchenpauer). The two species are so much alike that small specimens cannot be differentiated by the naked eye, but they differ noticeably in the form of the hydrothecae, and the position of the anterior sarcothecae, as well as in the spinous processes which distinguish *P. scabra*.

One of Kirchenpauer's figures—Pl. v., fig. 4b.—is good, only erring in showing a septal ridge on the proximal side of the anterior sarcotheca, instead of between it and the hydrotheca. As Allman has already noted, the stout spines which towards the tips of the branches replace the hydrocladia, are not, like the latter, jointed to the bracket-like apophyses, but are continuous with them. Between these and the ordinary hydrocladia, however, transition forms are found, which, commencing as hydrocladia, terminate in the characteristic spines.

The hydrocladia are so delicate as to appear like a fringe of fine cilia, and the hydrothecae far too small to be conspicuous to the naked eye; the habit is correctly shown in Kirchenpauer's figure (which agrees exactly with a drawing by Mr. Busk), and therefore differs widely from Allman's figure.

PLUMULARIA ROTUNDA M. and T. (Plate XVII, Fig. 1).

Plumularia delicatula var. rotunda, Mulder and Trebilcock, Geel. Nat. (2), iv., 1911, p. 116, pl. ii., fig. 2.

Hydrocaulus monosophonic, pinnate, stem divided into long internodes, each bearing a hydrocladium but no hydrothecae. Hydrocladia alternate, borne near the summit of the stem-internodes, the first internode short, without appendages, the others alternately long and short, only the former bearing hydrothecae.

Hydrothecae elliptic, lying along the internode, front wall arched, becoming thicker towards the aperture, where it is incurved; aperture small, oblique, margin concave at the sides, not everted, back entire, free.

Sarcothecae bithalamic, canaliculate, one below each hydrotheca and two lateral above, one on each intermediate internode, one (or two ?) in each axil, and one on the lower part of each stem-internode, median ones stout and fixed, laterals thinner, moveable?

Gonosome. ?

Loc.—Bream Creek, Pt. Phillip, (M. and T.).

I have only seen one specimen, which was about 3 mm. in height, but was incomplete. It is most nearly related to *P. delicatula* and *P. setaceoides* so far as the trophosome is concerned. The portion of the hydrothecal internode above the hydrotheca is often divided off by a distinct constriction.

The most characteristic feature is the form of the hydrothecae, which in side view are considerably stouter than those of *P. delicatula*, with the base more elevated; while the incurved thickened lip is also peculiar. In *P. delicatula* the border is convex at the sides, in *P. rotunda* it is concave, and more contracted. Only one sarcotheca was seen in each axil, but as in one case it was at the back instead of in front, it is not unlikely that there may have been originally two. On the processes supporting the hydrocladia thin places could be detected, with apparent apertures, but not forming distinct mammilliform prominences, as in many species.

PLUMULARIA EVERTA M. and T. (Plate XVII., Fig. 2).

Plumularia everta, Mulder and Trebilcock, Geel. Nat. (2), iv., 1909, p. 31, pl. i., fig. 5.

Hydrocaulus monosiphonic, pinnate, lower part with stout perisarc, divided by indistinct transverse joints at irregular intervals, and bearing sarcothecae only; upper part thin, divided by long oblique joints into internodes, each bearing a hydrocladium and a hydrotheca. Hydrocladia alternate, the first internode (or two internodes) very short, without appendages, the rest alternately long and short, only the former bearing hydrothecae.

Hydrothecae swollen and rounded below, strongly contracted on the adcauline side a little below the aperture, which is entire and slightly everted at the back.

Sarcothecae bithalamic, canaliculate, one below each hydrotheca and two lateral above (pedunculate), one midway between every two hydrothecae, on the intermediate internode (or, on the stem, on the same internode as the lower), two in line on each of the lower stem-internodes, and a few on the hydrorhiza; those in front of the hydrothecae stout and fixed, the rest moveable.

Gonosome?

Loc.—Torquay, Vic. (M. and T.).

Readily distinguished by the peculiar form of the hydrothecae. These have the adcauline side, where it is recurved under the everted margin, much thickened and in certain positions of the hydrotheca it looks like an intrathecal ridge.

Most commonly the intermediate internodes on the pinnae are distinct, but sometimes the nodes are wanting, so that the superior sarcotheca is on the hydrothecal internode, and this is normally the case with the stem. The robust lower part of the stem, with its transverse nodes, contrasts strongly with the delicate oblique-jointed upper part, which, in the only specimen I possess, is only about half the total height (5 mm.). I quote from Mulder and Trebilcock in regard to the sarcothecae of the lower stem, and of the hydrorhiza, which I have not seen. On the hydrocladia the first internode after the basal ones supports a sarcotheca only.

PLUMULARIA BALEI Bartlett. (Plate XVII., Fig. 6).

Plumularia balei, Bartlett, Geel. Nat. (2), iii., 1907, p. 65, fig. —. Mulder and Trebilcock, Geel. Nat. (2), iv., 1909, p. 29, pl. i., figs. 1-3. Briggs, Records Aust. Mus., xii., 1918, p. 41, pl. v., fig. 8-10.

Not *Plumularia halei*, Billard, Arch. de Zool. exp. et. gén. (5), viii., 1911, p. lxiii., fig. 3.

Hydrocaulus monosiphonic, pinnate, about 8 mm. in height, two or three indistinctly divided internodes at the base of the stem without pinnae, the rest divided by oblique joints into short internodes, each of which bears a hydrotheca and a hydrocladium. Hydrocladia alternate, the first internode (or two internodes) very short, without appendages, the others alternately short and long, only the latter bearing hydrothecae.

Hydrothecae reflexed, a strong inflexion in front partly filled up by perisarc externally, and extended into an intrathecal ridge reaching half through the hydrotheca; aperture large, margin produced into a long pointed peak in front, the sides elevated into two broad convex lobes, back forming a smaller lobe, free, a small, narrow lobe behind each lateral sarcotheca.

Sarcothecae bithalamic, canaliculate, one below each hydrotheca and two lateral above, one at the back of each hydrotheca on the pinnae, and two abreast in the corresponding position on the stem, one midway between every two cladiate hydrothecae, on the intermediate internode, and a few on the lower part of the stem; all sarcothecae rigid, the laterals mounted on very long peduncles which run up the sides of the hydrotheca nearly to the margin.

Gonothecae—female, broad, pyriform, truncate a little above the widest part, operculate, margin with a thickened band, about three or four sarcothecae near the base; male, much smaller, ovate, with one sarcotheca; both sexes on the same hydrocaulus, but the female on the lower cladiate portion and the male higher up.

Loc.—Bream Creek (Bartlett), Queenscliff (Mrs. Bartlett), Airey's Inlet (Mulder).

A remarkable species, possessing the extreme development of the lateral peduncles which characterises the genus *Halopteris* of Allman, not generally accepted. The lateral sarcothecae, which are stout and rigid, and entirely open on one side, are consequently elevated above the hydrotheca. The fixed anterior sarcothecae are strongly curved over towards the hydrothecae, as in *P. buski*, etc. The internodes of the stem, in front view, have a more or less fusiform shape. The intermediate internodes of the hydrocladia are shorter than I have seen them in any other species, and the joints above them are very oblique.

There is a certain similarity between this species and the *P. conspecta*[1] of Billard; in the latter, however, there are no intermediate internodes on the pinnae, but every internode (except the first) supports a hydrotheca, there is no intrathecal ridge, and the arrangement of the sarcothecae is different.

P. balei Billard, is a different species, also of the *Halopteris* type. It is now referred to the genus *Antennella*.

PLUMULARIA CORRUGATISSIMA M. and T. (Plate XVII., Fig. 3).

Plumularia setaceoides, var. *corrugata*, Mulder and Trebilcock, Geel. Nat. (2), iv., 1911, p, 118, pl. ii., fig. 8.

Plumularia corrugata, Mulder and Trebilcock, Geel, Nat. (2), vi., 1914, p. 43, pl. v., fig. 3.

Plumularia corrugatissima, Mulder and Trebilcock, Geel, Nat. (2), vi., 1915, p. 53.

Not *Plumularia corrugata*, Nutting, Amer. Plum., 1900, p. 64, pl. vi., figs. 1-3.

Hydrocaulus monosiphonic, pinnate, about 12 mm. in height, stem divided by oblique joints into short internodes, each supporting a hydrocladium but no hydrothecae; hydrocladia alternate, borne about the middle of the stem-internodes, the first internode short, without appendages, the others alternately long and short, only the former bearing hydrothecae.

Hydrothecae very small, cup-shaped, with the front contracted below the everted lip; aperture entire, somewhat oblique, back adnate as far as the margin.

Sarcothecae bithalamic, canaliculate, one below each hydrotheca and two lateral above, one midway between every two hydrothecae, on the intermediate internode, two in each axil, and one just above the base of each pinna, all rather thin-stemmed and apparently moveable.

Gonosome?

Loc.—Torquay, Barwon Heads, Spring Creek, (M. and T.).

A small form not closely related to any of our known species. The hydrothecae differ from those of *P. setaceoides* in not being free at the back, and rather resemble those of *P. scabra*, but it is doubtful to what extent the contraction below the lip exists in life, as the specimen shows apparent sign of shrinkage at that part. The strong development of the internal ridges of the perisarc gives to the species a very characteristic corrugated appearance.

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1 Arch. de Zool. exp. et gén. (4), vii., 1907, p. 362, fig. xi.

PLUMULARIA LAGENIFERA Allman.

Plumularia lagenifera, Allman, Journ. Lin. Soc., Zool., xix., 1885, p. 157, pl. xxvi., figs. 1-3. Nutting, Amer. Plum., 1900, p. 65, pl. vi., figs. 6-10. Torrey, Univ. of Calif. Publ., Zool., i., 1902, p. 77; var. *septifera*, p. 78, pl. xi., figs. 101, 102. Fraser, Bull. State Univ. Iowa, vi., 1911, p. 82.

Plumularia turgida, Bale, Proc. Linn. Soc. N.S.W. (2). iii., 1888, p. 779, pl. xx., figs. 12, 13.

Plumularia californica, Marktanner-Turneretscher, Ann. naturh. Hofmus., v., 1890, p. 255, pl. vi., figs. 4, 4a.

Plumularia setacea, Clark, Trans. Conn. Acad., iii., 1876, p. 261, pl. xli., figs. 1, 2.

The *P. lagenifera* of Allman, as well as *P. multinoda*, described in the same paper, was represented as possessing several short internodes, instead of one, between every two hydrothecae. Nutting, however, who has examined Allman's types, finds that this supposed character is by no means constant, but that the hydrocladia in the specimens which he examined are composed of alternately long and short internodes, just as in *P. setacea*, etc. As *P. turgida*, though certainly not agreeing with Allman's description, seems to differ in no essential from the form described by Professor Nutting, I exchanged specimens with that gentleman, who considers the two forms to be referable to the same species. *P. californica* M.-T., is, according to Nutting, *P. lagenifera* with the septal ridges well developed, as in Torrey's var. *septifera*. Torrey finds in *P. lagenifera* 1-4 short internodes at the base of the hydrocladia, and 1-3 between the hydrothecal internodes; but he says that in var. *septifera* the intermediate internodes are single. Fraser finds that some specimens have 2-3 short internodes at the base of the hydrocladia, and occasionally more than one intermediate. But in all cases where more than one occur together only one of them bears a sarcotheca. In the few specimens which I have seen from California and Australia, I have not met with any instance of this repetition of the short internodes.

The strong development of the septal ridges is not invariable; in some specimens it is not much more pronounced than in *P. setacea;* often, however, these ridges are more thickened, quite encircling the interior of the internodes, and sometimes being accompanied by external constrictions which add to the charac-

teristic wrinkled appearance. But great variation in the strength of the septal ridges is a general character of many species, and has of itself no specific value. Neither in the Californian nor the Australian specimens which I have examined was there, in the main stem, more than an occasional slight indication of septal ridges.

The species is extremely close to *P. setacea*, and when describing *P. turgida* I had considerable doubt as to their specific relationship. I cannot find any definite and constant distinction other than the more ventricose condition of the hydrothecal internode in *P. lagenifera*, while the hydrotheca itself is (in side view), but little, or sometimes not at all, widened from the base upward. My specimens of *P. lagenifera* have two sarcothecae in the axils, while *P. setacea* has one; the distinction, however, may not be constant.

Nutting says that specimens from Yale University Museum, labelled "Coast of California," marked *P. setacea*, belong undoubtedly to *P. lagenifera*. Presumably these are the specimens which Clark referred to *P. setacea*. He described them as having two sarcothecae in each axil, and his figure agrees better with *P. lagenifera*.

Stechow considers that Inaba's "No. 5 *Plumularia* sp." also belongs here, but it agrees much better with the minute form described by me as *P. caliculata* (q.v.).

Plumularia caliculata Bale.

Plumularia caliculata, Bale, Proc. Lin. Soc. N.S.W. (2), iii., 1888, p. 780, pl. xx., figs. 9-11.

No. 5 *Plumularia* sp., Inaba, Zool. Mag. Tokio, 1890, figs. 11-13.

Plumularia lagenifera, Stechow, Hydroidpolypen der jap. Ostküste, ii., 1913, p. 90, figs. 57, 58.

P. caliculata is a dwarf species, my specimens of which range from 8 to 10 millimeters in height; the trophosome is almost a miniature of that of *P. setacea* except that the hydrothecae are shallower and the septal ridges usually more pronounced. These ridges are often conspicuous in the main stem, a feature which I have not observed in *P. setacea* or *P. lagenifera*. This character, however, is variable, and in some specimens the ridges are less developed. The hydrothecae are shallower than those of *P.*

lagenifera, and, as seen laterally, are not so wide proportionately at the base, nor are the internodes supporting them so turgid.

Inaba's description agrees precisely in all particulars of specific value with my specimens, allowance being made for his use of the term "joint" for the areas between the septal ridges as well as those between the true nodes. Thus when he says that there are three joints in the stem between two successive branches, it is meant that the internode is divided into three parts by two septal ridges. It is to be noted, however, that the intermediate internodes of the hydrocladia sometimes have really a secondary node dividing them into two, and this would seem to have been more frequently the case in Inaba's specimen than in my own, since he refers to it as the normal condition.

Inaba says: "This species is very small, being less than 10 mm. high, the branches are short, and being all of about the same length this species can easily be distinguished from *P. setacea* by its general form. On a closer examination, however, the number and arrangement of the nematophores are found to be exactly the same as in *P. setacea*. If in *P. setacea* each joint of the stem were divided into three, and each short joint of the branches into two, the arrangement would be exactly what we find in the present species. Moreover the joints do not appear to be absolutely fixed in this species, being sometimes irregular; in the lower part of the stem particularly three joints are frequently united into one.

"The more minute differences from *P. setacea* are as follows:—The comparative shortness of the stem, the comparative thickness of the perisarc, the comparatively small size and greater number of the joints, the comparative shallowness of the bowl-shaped hydrothecae, and the fact that there are always two on each branch."

The last-mentioned character is, as might be expected, not invariable; in some of my specimens the hydrothecae are limited to two on a hydrocladium, in others there are three.

The gonangia are about .55 mm. in length, the male form has sides straight, so that the width is about the same throughout except at the base and the summit; the terminal portion is blunt, directed to one side and sometimes slightly narrowed, with an oblique aperture. Female capsules observed were somewhat widened in the middle, and very broad at the extremity; these were, however, probably immature, as other specimens were seen, empty, which were more contracted towards the aperture. Inaba's specimens were without the gonosome

Nemertesia cylindrica Kirch.

Plumularia cylindrica, Kirch., Abh. Nat. Ver. Hamb., vi., 1876, p. 45, pl. i., fig. 1, pl. iv., figs. 1, 1b.

Antennularia cylindrica, Bale, Cat. Aust. Hydr. Zooph., 1884, p. 146, pl. x., fig. 7.

Sciurella indivisa, Allman, Chall. Plum., 1883, p. 26, pl. v., figs. 1-4. Kirkpatrick, Sci. Proc. Roy. Dubl. Soc. (N.S.), vi., 1890, p. 609. Billard, C.R. Acad. d. Sci., cxlvii., 1908, p. 759.

Nemertesia indivisa, Billard, Ann. Sci. Nat. (9), xi., 1910, p. 38. Idem, Siboga-Exp., 1913, p. 60, fig. 5.

This species has been referred to different genera on account of variations in the arrangement of the hydrocladia in different specimens, or even in various parts of the same specimen. Kirchenpauer described his *P. cylindrica* as having a doubly pinnate arrangement, one pinna standing in front of another on each side of the rachis. Kirkpatrick says—"At first the arrangement of the ramules is bipinnate, each half of the pinna being composed of ramules arranged two deep. Higher up the bipinnate arrangement is obscured, the ramules growing along three or four sides of the stem, as in *Antennularia.*" Allman says that the hydrocladia are "in four longitudinal alternating series"; in other words, that they are in alternating opposite pairs, as in *N. decussata*. I find, however, in a fragment of his material (for which I am indebted to Dr. Kirkpatrick), that they are in sets of three, alternating with those above and below, so that there are six longitudinal series, and all my own specimens are similar to the last.

There is no doubt as to the identity of *A. cylindrica* and *S. indivisa*, Dr. Kirkpatrick having compared type specimens of both; and there seems no reason to doubt that Kirchenpauer has described the same species. Kirkpatrick has remarked that Kirchenpauer's figure shows the superacalycine sarcothecae as lower down than those of *S. indivisa*, but the difference is very slight, especially in Kirchenpauer's Plate IV.; moreover, it is accentuated by the calycle-margin being shown too high, as Kirchenpauer, like Allman, fails to notice the slight sinuations of the border where it joins the hydrocladium. As Billard has observed, the sarcothecae spring from just *inside* the hydrotheca-margin.

The British Museum specimen includes several gonangia, which are irregularly lobed, as shown by Billard in his "Siboga" Report, and not as figured by Allman. In all the specimens

examined by me the elevation from which the mesial anterior sarcotheca springs is decidedly more pronounced than in Kirchenpauer's and Allman's figures.

Lytocarpus phillipinus Kirch.

Aglaophenia phillipina, Kirch., Abh. Nat. Ver. Hamb., v. 1872, p. 45, pls. i., ii., vii., fig. 26.

Aglaophenia urens, Kirch., Abh. Nat. Ver. Hamb., v., 1872, p. 46, pls. i., ii., vii., fig. 27. Bale, Cat. Aust. Hydr. Zooph., 1884, p. 155, pl. xiv., fig. 6, pl. xvii., fig. 9. Hincks, Journ. Lin. Soc. (Zool.), xxi., 1889, p. 134.

Lytocarpus phillipinus, Bale, Proc. Lin. Soc. N.S.W. (2), iii., 1888, p. 786, pl. xxi., figs. 5-7. Marktanner-Turneretscher, Ann. des k.k. naturh. Hofhus., v. 1890, p. 274, pl. vi., fig. 16. Kirkpatrick, Sci. Proc. Roy. Dubl. Soc. (N.S.), vi., 1890, p. 604. Pictet, Rev. Suisse de Zool., i., 1893, p. 60, pl. iii., fig. 53. Nutting, Amer. Plumul., 1900, p. 122, pl. xxxi., figs. 4-7. Weltner, Semon, Zool. Forschungs. in Aust. u. dem Malay Arch., 1900, p. 587. Jäderholm, Arkiv för Zoologi, k. svenska Vetens. i., 1903, p. 298. Billard, Arch. Zool. exp. et gén. (4), vii., 1907, p. 377, fig. xviii. Idem., Siboga-Exp., i., Plum., 1913, p. 78. Thornely, Journ. Lin. Soc. (Zool.), xxxi., 1908, p. 84. Fraser, Bull. Bureau of Fisheries, xxx., 1910, p. 379, f. 45.

Lytocarpus urens, Bale, Proc. Lin. Soc. N.S.W. (2), iii., 1888, p. 789.

Not *Lytocarpus phillipinus*, Congdon, Proc. Amer. Acad. A. and S., xlii., 1907, p. 484, fig. 37.

Having had the opportunity of examining fertile specimens of *L. urens* from Moreton Bay I have now no doubt as to their specific identity with *L. phillipinus*. The slight difference in the form of the hydrothecae indicated by Kirchenpauer is inconstant, both forms having lateral lobes which often tend to become obsolete. The gonangia are described as large in *L. phillipinus* and unusually small in *L. urens*, a difference which appears to be merely sexual, *L. phillipinus* being the female form and *L. urens* the male.

The gonocladia occur at somewhat irregular intervals, taking the place of hydrocladia. In the female there are usually about 6-10 internodes, two, or sometimes only one, of which bear gonangia. The others bear mostly three sarcothecae, apparently representing those of the suppressed hydrothecae; but they are often quite irregular. There is a hydrotheca on the proximal part of the gonocladium, and generally one or two abortive ones also. In the male the gonocladium, according to Kirchenpauer, bears one gonangium, immediately above which it is abbreviated. In most instances, however, I found one or two internodes above the gonangium, with sarcothecae similar to those on the female. The proximal hydrotheca seems absent in most cases. The condition is analogous to that of many of the *Aglaopheniae*, in which the protective structures surrounding the gonangia are more developed in the female than in the male, though similar in kind.

In these specimens the thread-cells are large and numerous, and are found abundantly in the interior of the tubes of the perisarc, just as in my former specimens of *L. phillipinus*. Kirchenpauer figures these bodies in that species, but does not mention their presence in his description of *L. urens*. He refers, however, to the powerful urticating properties of both forms.

Congdon's "*L. phillipinus*" has no resemblance to Kirchenpauer's species.

AGLAOPHENIA SINUOSA Bale.

Aglaophenia sinuosa, Bale, Proc. Linn. Soc. N.S.W. (2), iii., 1888, p. 790, pl. xxi., figs. 1, 2.

A. sinuosa and the species or variety next to be described are somewhat exceptional among the Australian species in the monosiphonic habit, a feature more common among the *Halicornariae*, as also is the possession of a cauline sarcotheca situated at the back of each axil.

The lower part of the stem bears sarcothecae but no hydrocladia, and when the stem bifurcates, as is often the case, the cladiate portion commences only above the bifurcation. One specimen has the stem divided at about 5 mm. above the base, and each branch again subdivides about 2 mm. higher, while in another only one of the primary branches is again divided, but in none of the specimens observed are hydrocladia found below any of the bifurcations.

The corbulae observed (or some of them) were female, free planulae being present in one or two instances. The corbulae

average about 2.5 mm. in length, with the rachis straight and the front arched, the rows of sarcothecae strongly oblique, and each consisting of about six sarcothecae of some .148 mm. in length; the colour rather dark red-brown.

AGLAOPHENIA BAKERI, n. sp. (Plate XVII., Fig. 7-8).

This species, which was collected at Western Port by Mr. F. H. Baker, is an extremely close ally of *A. sinuosa*, of which it may perhaps prove to be a variety. The structure as regards the stem and branches is identical, but the hydrocladia are less divergent in the present form than in *A. sinuosa*, where they stand off at a rather wide angle, with the two cauline sarcothecae in a line about at right angles to the base of the hydrocladium, and therefore diagonal to the stem-internode. In *A. bakeri* these sarcothecae are in a line very oblique to the hydrocladium, and much more nearly parallel with the axis of the stem.

In the number and form of the hydrotheca-teeth the two species are nearly alike, but in *A. sinuosa* (as seen in exact profile) the first tooth on each side appears narrow, the second and third wider and nearer together, and the fourth very narrow; while in *A. bakeri* the first looks wider, the second rather smaller, and the third about as large as the first, the fourth being very minute or obsolete. This description applies to typical hydrothecae, but the characters are rather inconstant.

There is a difference in the posterior intrathecal ridge, which in *A. sinuosa* extends half through the hydrotheca, but in *A. bakeri* is narrower. But the most patent distinction is in the lateral sarcothecae, which, as seen in the front view of *A. sinuosa*, are very large and prominent, a feature not found in the present species.

Only two corbulae were observed, both on the same branch, and the sex was not determinable. They are about 3 mm., in length, and therefore somewhat longer than those of *A. sinuosa*, lighter in colour, with about eleven pairs of leaflets. The rows of sarcothecae are less oblique than those of *A. sinuosa*, and the sarcothecae themselves are smaller (about .104 mm.). In contrast to the condition in *A. sinuosa*, where the front of the corbula is regularly arched, so that it becomes gradually narrower towards the ends, these corbulae are widest near the ends, and they are somewhat constricted at two places near the middle, at which part the form of the leaflets and the arrangement of the sarcothecae become irregular. But possibly these peculiarities may be merely abnormal.

AGLAOPHENIA BRACHIATA (Lamarck).

Plumularia brachiata, Lamarck, An. s. Vert., ii., 1816, p. 126. Blainville, Man. d'Act., 1834, p. 478.

Aglaophenia crucialis, Kirchenpauer, Abh. Nat. Ver. Hamb., v., 1872, p. 26, pl. i., fig. 8. Bale, Cat. Aust. Hyd. Zooph., 1884, p. 168, pl. xviii., fig. 8.

Thecocarpus crucialis, Billard, Ann. Sci. Nat. (9), v., 1907, p. 328, figs. 3, 4.

Aglaophenia carinata, Bale, Proc. Roy, Soc. Vict. (N.S.), vi., 1893, p. 105, pl. vi., figs. 1.3.

Thecocarpus brachiatus, Billard, C.R. Acad. d. Sci., cxlviii., 1909, p. 1064; Idem, Ann. Sci. Nat. (9), ix., 1909, p. 331.

My best specimen of this species is about 10 inches high by four wide, and as each of the main branches has its minor branches in the same plane the whole polypary forms a flattened frond. It is very freely branched and rebranched from the base up. Another specimen differs so much in general appearance that without microscopical examination it might be supposed a different species; this is owing to its irregular and bushy habit, the branches being much contorted and tangled-looking; it also has extremely short hydrocladia. But I can find no difference in the form of the hydrothecae or other minute structure.

There is nothing specially noteworthy in the method of branching, such as might be inferred from Lamarck's description, the branches being given off mostly in pairs from two successive internodes of the primary stem-tube, just as in the *crucialis* group, and therefore taking the place of two hydrocladia. But they are more numerous and closely set than I have observed them in *A. macrocarpa* and its allies, where they are usually more distant and straggling.

The corbulae seen are of similar type to those of the *crucialis* group, closed, but having a series of openings at the bases of the leaflets, over which project the lateral spurs given off from the leaflets next behind. These spurs are stout but short, and for the most part support only two receptacles, terminal in position; the inferior is a conical sarcotheca, rather narrower than those on the ribs, the superior, which projects rather beyond it, is mostly broader and is considered by Billard to be a hydrotheca. It does not appear so to me, and it is generally only about the middle of the

corbula that these cups are notably different from the ordinary sarcothecae; on the first leaflet or two they are usually quite similar, both in form and size, to the sarcothecae of the ribs; the succeeding ones are progressively broader, to about the middle of the corbula, while at the distal end they are again reduced to nearly the size and form of the ordinary sarcothecae. Often after attaining the maximum size the next one is bifurcated, forming two cups, as shown by Billard, who recognises that in this case they are true sarcothecae. Uusually the spur of the first leaflet (as well as of the supernumerary one which is generally present) bears only one sarcotheca instead of two; the next spur may have both the upper and the lower sarcotheca about equal in size, and then the gradual increase of the superior receptacles commences. The transition from the undoubted sarcothecae at the ends of the corbula to the largest of the cups near the middle is so gradual that I can find no line of demarcation such as we should expect if some of them were sarcothecae and others hydrothecae. The large cups are very irregular in the form of the border, but they have a deep marginal sinuation, a character common to all the sarcothecae, but not found in hydrothecae.

According to Billard the spurs support inferiorly a pair of sarcothecae, which he considers represent the laterals of the assumed hydrothecae; I cannot find any instance of this in my specimens, in which the inferior sarcotheca is single, and situated centrally, not laterally. In one or two instances I have seen this sarcotheca bifurcated, one branch then being above the other. The inferior sarcotheca is united by a web of perisarc to the superior cup.

The corbulae may very probably present sexual differences, but I have no means of ascertaining whether this is so, as all the corbulae observed by me were from the same colony. The sex was not determinable.

CLADOCARPELLA, Bale.

I have followed Nutting in regarding the genus *Cladocarpus* as characterized by the possession of phylactocarps which are limited to a single one on a hydrocladium, always springing from the base or the proximal internode; consequently on meeting with a species with the phylactocarps not limited to that position, but occurring on several internodes of the same hydrocladium, I proposed for it the genus *Cladocarpella*. The distinction is not very strong, and it is to be observed that Allman's original diagnosis of the genus *Cladocarpus* is wide enough to embrace such forms, and that

Billard has first made known one such (*C. sibogae*). Probably, therefore, many observers will prefer to regard *Cladocarpella* as at most a sub-genus.

Out of fourteen species of *Cladocarpus* included by Nutting among the American Plumulariidae, twelve have the characteristic gonosome as described above; in the other two it is unknown. A later species described by Allman—*C. pectiniferus*—has also the typical gonosome. In *Cladocarpella* a single hydrocladium may give origin to several phylactocarps consisting of distinct internodes, of which from one to three bear gonangia, while the remainder support only sarcothecae.

Cladocarpella multiseptata Bale.

Cladocarpella multiseptata, Bale, "Endeavour" Rept., Part iii., 1915, p. 304, pl. xlvii., figs. 1-5.

In the original description I have indicated the distinctions between this species and *Cladocarpus* (?) *bathyzonatus*, Ritchie, a closely allied form; and the *Cladocarpus sibogae* of Billard's "Siboga" Report is equally nearly related to the present species. In *C. sibogae* the hydrothecae seem in lateral view more gradually enlarged towards the aperture, and a more noticeable difference is in the septal ridges, which in *C. sibogae* number two to five, while in *C. multiseptata* there are about nine to fourteen. Billard says that these ridges are found only in certain internodes, and according to his figures these may be the most recently formed ones; but in *C. multiseptata* their presence or absence seems to be a matter of age, the proximal internodes having them, while those nearer the ends of the hydrocladia show no trace of them.

C. sibogae is said to have two to four sarcothecae between two hydrocladia, in *C. multiseptata* there are usually nine to twelve.

Cladocarpus multiapertus, Billard ("Siboga" Report) is sufficiently distinguished from these species by the sarcothecae, which are mostly provided with two orifices in addition to the lateral one. Its gonosome has not been observed.

Hydra, sp.

The brown hydra commonly found about Melbourne has been hitherto generally referred to *H. oligactis*, the only species which, according to Hincks, agrees with it in regard to the so-called "stalked" condition. Later researches, however, especially by

Dr. A. Brauer,[1] have established the fact that another European species exists, sharing with *H. oligactis* the stalked condition, but differing from it in several particulars not recognised by the older observers; and the description renders it probable that our common species may be associated with this new form, unless, which is not unlikely, it may prove distinct from both. It is also possible that more than one species may be represented among the forms which we have been accustomed to call *H. oligactis*.

Trembley, in his famous memoir, described three species, which he called the first, second, and third species (according to the order in which he observed them), and to British observers, at least from Johnston onwards, these have been known respectively as *H. viridis*, *H. vulgaris*, and *H. oligactis*. Continental observers have more commonly, in disregard of priority, referred to the two last as *H. grisea* and *H. fusca;* in many cases, however, they have confused the species, and, as Bedot remarks, have named their specimens solely according to their colour or their abundance, calling them *grisea*, *fusca*, or *carnea*, according as they are grey, brown, or rose, and *vulgaris* when they are very abundant. Brauer[2] himself, in an earlier paper, referred to the species subsequently found by him to be new, as *H. fusca*, and called the true *H. fusca* or *H. oligactis*, *H. sp.* In his later paper he corrects this, and reduces the European species to four, namely, *H. viridissima*, *H. vulgaris*, *H. oligactis*, and *H. polypus*. In regard to the first three, therefore, he comes into line with British observers, except that he errs in using the name *H. viridissima* instead of *H. viridis*. The newly established species, which he calls *H. polypus* Lin., is not Linné's *H. polypus*, as shown by Bedot,[3] who names the species *H. braueri*.

Annandale,[4] in his paper on the common hydra of Bengal, has described under the name of *H. orientalis* a species which he finds very nearly allied to *H. oligactis* (called by him *H. diaecia*), but which he considers distinct. It is abundant in India, and is the only species which he has found there.

Von Lendenfeld,[5] in 1885, described *H. hexactinella* from a pool

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1 A. Brauer—Die Bennennung und Unterscheidung der *Hydra*-arten. Zool. Anz., Bd. xxxiii., S. 790, 1908.

2 A. Brauer—Über die Entwicklung von *Hydra*. Zeitsch. f. wissensch. Zoologie, lii. 2, S. 169. 1891.

3 M. Bedot. Sur la Nomenclature des Hydres. Zool. Anzeig., Bd. xxxix., No. 19/20, 1912.

4 N. Annandale. The Common *Hydra* of Bengal. Mem. Asiatic Soc. of Bengal, I., No. 16, p. 339, 1906.

5 R. von Lendenfeld. *Hydra hexactinella*, nova species. Proc. Linn. Soc. N.S.W., x., pt. 4, p. 679, 1885.

at Moore Park, near Sydney, but the characters given do not suffice for identification.

The characters made use of by Brauer in discriminating the species include, in addition to those recognized by the older observers, the sexual condition, the form of the egg, and the number of distinct forms of nematocysts present. Without these details identification is uncertain.

For the assistance of observers who may engage in the study of our local species, I append the following diagnoses, compiled from the descriptions of Brauer and Annandale and other authors.

H. viridis Lin.—Body cylindrical or gradually more slender towards the lower extremity, not stalked. Tentacles 6-10, shorter than the body. Three sorts of nematocysts. Hermaphrodite. Egg spherical, with reticulated, nearly smooth surface. Colour grass-green. Syn.—*H. viridissima* Pallas; *H. gracilis* Agassiz.

H. vulgaris Pallas.—Body cylindrical, not stalked. Tentacles 7-12, little longer or not longer than the body. Four sorts of nematocysts. Hermaphrodite. Egg spherical, set with coarse spines which are expanded or bifid at the tips, deciduous, Colour brown, orange, gray, reddish, yellowish. Syn.—*H. grisea* Lin., *H. attenuata* Pallas,? *H. aurantiaca* Ehrenberg, *H. rubra* Lewes, *H. brunnea* Templeton, *H. trembleyi* Haacke.

H. oligactis Pallas.—Body "stalked," 2-3 cm. long. Tentacles 6-8, long, capable of great extension to several times as long as the body. Three sorts of nematocysts. Dioecious. Gonads on the whole body except on the stalk-like part. Eggs mostly adherent in groups, subspherical, with very short simple spines. Colour, gray, brown, reddish. Syn.—*H. fusca* Lin., *H. carnea* Agassiz, *H. rhaetica* Asper, *H. roeseli* Haacke, *H. rhistica* Asper, *H. verrucosa* Templeton, *H. dioecia* Downing.

H. braueri Bedot. Body "stalked," not more than 2 cm. long, mostly 1-1½. Tentacles much longer than the body. Four sorts of nematocysts. Hermaphrodite. Gonads borne only on the distal part of the body. Eggs attached singly, convex above, with short simple spines, flat and smooth below. Colour, gray, brown. Syn.—*H. polypus* Brauer (not Lin.)

H. orientalis Annandale.—Body "stalked," 1½-3 cm. long. Tentacles 5-6, long, capable of great extension (to 3-6 times as long as the body). Three sorts of nematocysts. Dioecious. Gonads confined to the upper part of the body. Normal eggs spherical, set with fine spines which are bifid or expanded at the tip. Abnormal

eggs (pathological) smooth, with a small projection at the distal pole. Colour, orange-brown to deep olive-green.

H. attenuata Pallas.—Brauer says that this is Rösel's "straw-yellow polyp," that it has never been found again, and that it is probably only a colour-variety of *H. vulgaris.* Brauer strangely overlooks the remarks of Johnston, who observed this form. He says: "This, which is represented very exactly in the plates of Rösel's beautiful work, is a larger animal than *H. vulgaris*, and comparatively rare, less sensible to external impressions, and of a more gracile form. Its colour is a dilute olive-green, with paler tentacula, which are considerably longer than the body, and hang like silken threads in the water waving to and fro without assuming that regular circular disposition which they commonly do in the *H. viridis.*" Hincks, however, like Brauer and Bedot, thinks is is probably a variety of *H. vulgaris.* Syn.—*H. pallens* Lin.

H. hexactinella von Lendenfeld.—Von Lendenfeld describes the body as perfectly cylindrical, and 15 mm. in length, while the tentacles when fully extended, are said to reach only 5 mm. The body is colourless, and there are two sorts of nematocysts. "It can be distinguished from other Hydras by the constancy in the number of arms, which is invariably six. These tentacles are all equal in length and thickness, and the angles between them are perfectly equal, measuring 60°. Such regularity has been observed in no other species. It appears that in this respect our Hydra is more highly developed than the others, as the number of antimeres has been defined."

The "stalked" condition referred to in these descriptions is not a permanent character, but is merely a distension resulting from recent feeding, which affects only the upper part of the body, so that the lower part has by comparison a stalk-like appearance. The young *Hydra*, so long as the body-cavity communicates with that of the parent, assumes a similar form when food has been taken by the latter. This differentiation of the alimentary tract, practically into stomach and intestine, marks a higher stage of development than that attained by such forms as *H. viridis.*

Jickeli, in his paper on *Hydra*[1] figures the four different forms of nematocysts found in the genus. First we have the large form, which has a stout ovate capsule, truncate at the smaller end, with a

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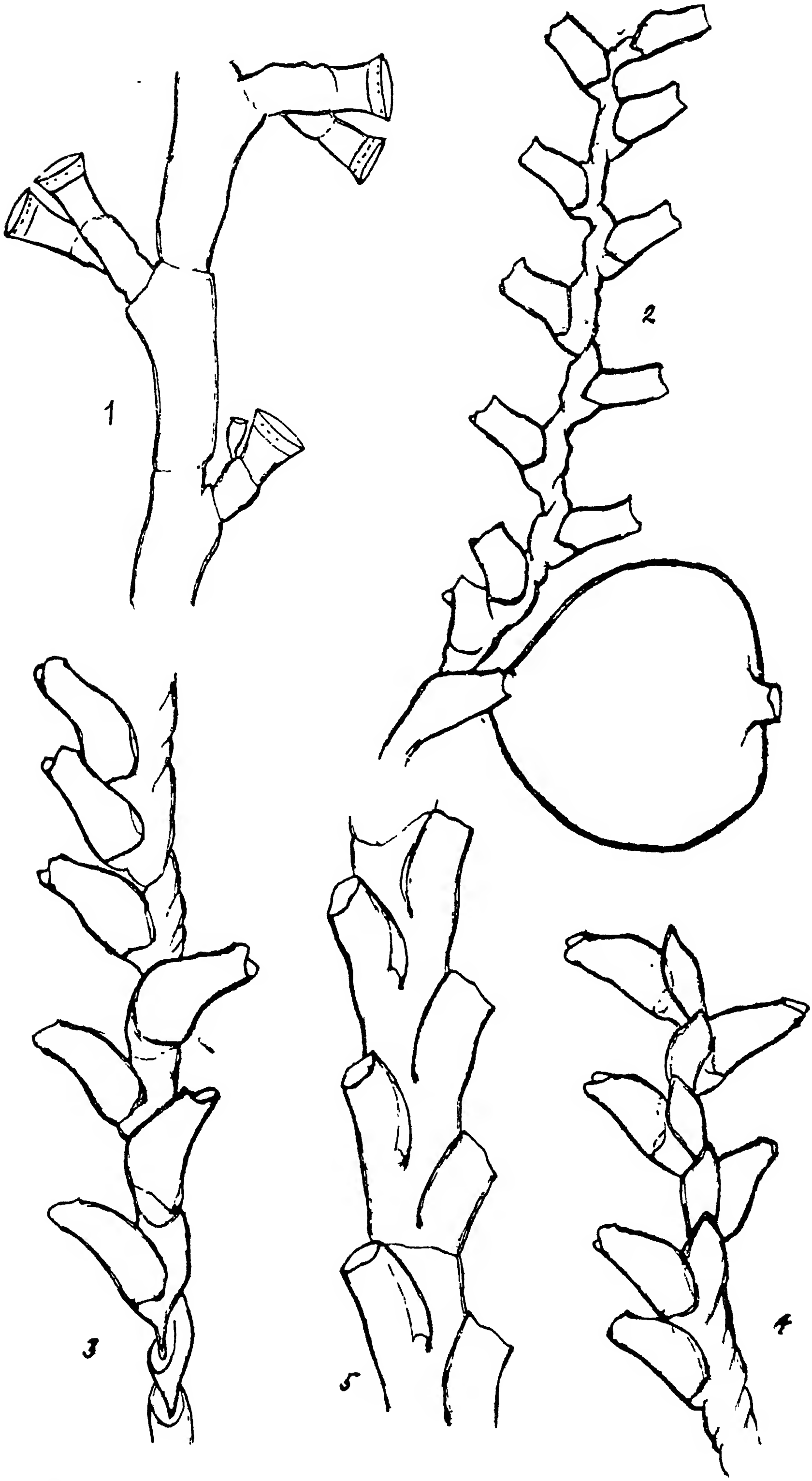
1 C. F. Jickeli. Ueber den histiologischen Bau von *Eudendrium* Ehrb. und *Hydra* L. Morpholog. Jahrb., Bd. viii., p. 373, T. xviii., figs. 1-3. (In fig. 3 the lettering is evidently wrong, the letters β and γ—called *b* and *c* in the text—should be transposed).

thread many times the length of the capsule, barbed, and coiled round the longitudinal axis. Secondly, the small form, nearly round, containing a short smooth thread, which forms a spiral oı one coil only. These two types are found in all the species. In *H. oligactis* (called by Jickeli *H. vulgaris*) is found a third sort, consisting of an oblong or elliptic capsule, as long as the large form, but much narrower, with a barbed thread which forms two or three loose loops running lengthwise. *H. vulgaris* (*H. grisea* of Jickeli) also has this type, and in addition a fourth form, of medium size, with a barbed thread coiled about the longitudinal axis. The last form occurs in *H. viridis* also. According to Jickeli's figures the large nematocysts of *H. vulgaris* much exceed in size those of the other species figured by him. Brauer, in his paper of 1908, describes his *H. polypus* (*H. braueri*) as having, like *H. vulgaris*, four sorts of nematocysts, and remarks particularly that the large form is much larger than the corresponding form in *H. oligactis*. In *H. orientalis*, according to Annandale, there occurs occasionally a form intermediate in size between the large and the small forms, but whether of the third or the fourth type mentioned above is not stated. Von Lendenfeld says that *H. hexactinella* has two sorts of cnidoblasts, with different cnidocells.

Brauer, in his paper of 1891, figures the eggs of the four European species admitted by him. *H. oligactis* is there called *H. sp.?*, *H. vulgaris* is called *H. grisea*, and the form now named *H. braueri* is called *H. fusca*.

I am not aware of any observations on Australian Hydras covering the features which, according to the foregoing descriptions, are necessary to be considered in discriminating the species. All the brown hydras which I have seen agree in the so-called "stalked" condition. When empty and fully extended the body may attain quite an inch in length. Specimens which I collected at Williamstown many years ago, after being kept some time, were found capable of extending the tentacles to three inches in length; others found more recently at Kew did not display this character during the short time they lived. The number of tentacles varied between 5 and 8, but in the great majority of cases there were six. I have not observed the eggs in any case.

The character upon which von Lendenfeld founds his *H. hexactinella* is unreliable, as the mere fact that a number of specimens from a single pool agreed in possessing six tentacles cannot prove the invariability of the species in this respect. In a



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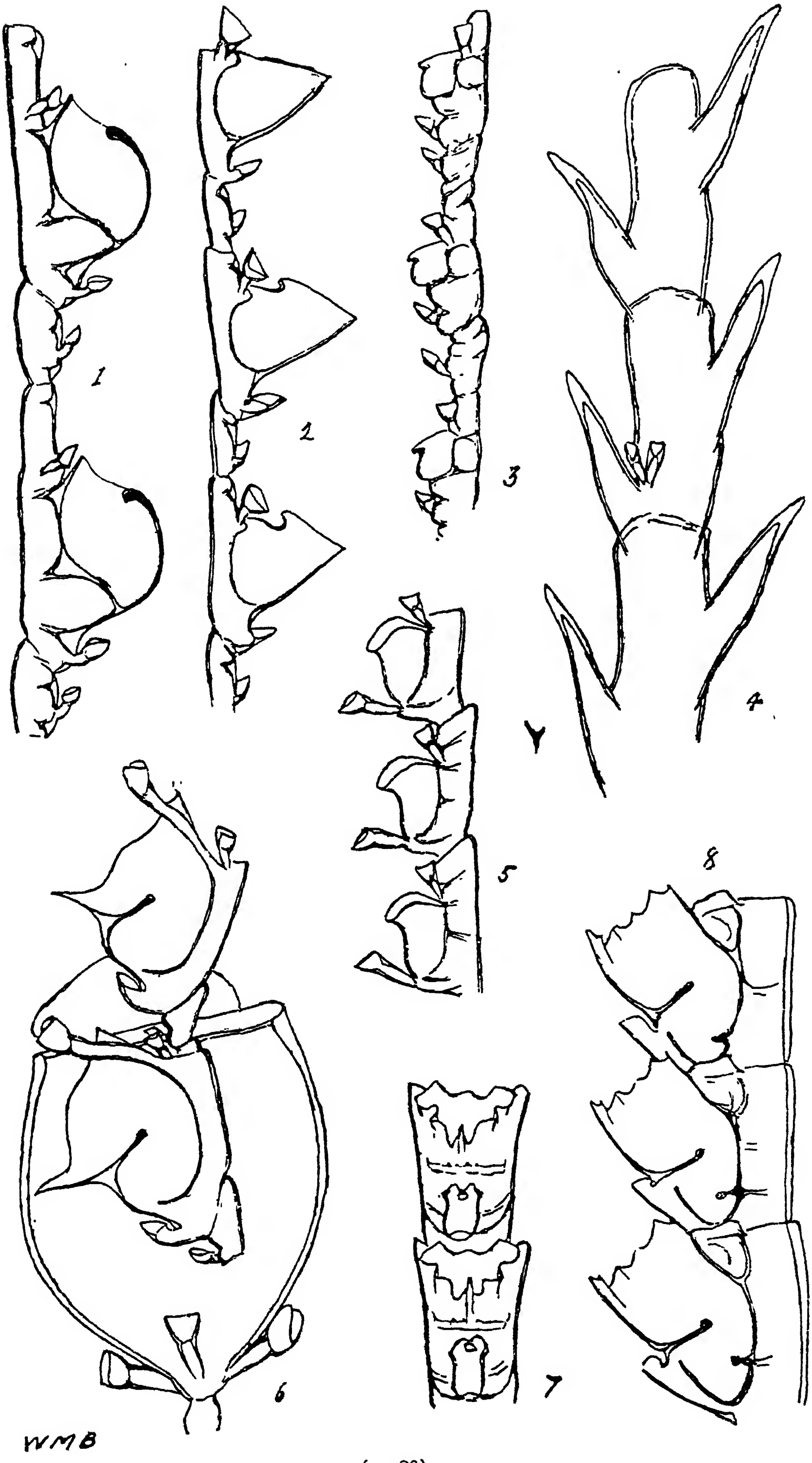


(× 80).

slide of *H. hexactinella* sent to me by Mr. Whitelegge, who first observed it, two hydranths out of seven possessed five tentacles only. Sexual products were apparently not observed.

I have seen only the two usual forms of nematocysts in such Hydras as I have examined, but I should hesitate, in the absence of full series of sections, to decide that no others were present, as the intermediate types appear much less common, and more likely, from their delicate structure, to be overlooked. In the specimens of *H. hexactinella* I find the large form in two distinct sizes, averaging respectively about 13μ and 10μ in length, both sizes being very abundant, while intermediate ones are very rare. In some sections of the common species which I have seen the large nematocysts measured about 15μ.

Judging from Mr. Whitelegge's specimens I have no doubt that *H. hexactinella* is one of the "stalked" forms, and I think that Von Lendenfeld was mistaken in stating the length of the tentacles, when fully extended, as only 5 mm., or one-third the length of the body. The figure shows the body very long and slender, and the tentacles short, but the case is probably similar to that of *H. orientalis*, of which Annandale says that when the body is very much elongated, the tentacles are never fully extended.

EXPLANATION OF PLATES.

Plate XVI.

Fig. 1.—*Ophiodes australis*, n.sp.
Fig. 2.—*Sertularella rentoni* Bartlett.
Fig. 3.—*Sertularia McCallumi* (Bartlett).
Fig. 4.—*Sertularia McCallumi* (Bartlett).
Fig. 5.—*Sertularella diaphana* (Allman).

× 40.

Plate XVII.

Fig. 1.—*Plumularia rotunda* Mulder and Trebilcock.
Fig. 2.—*Plumularia everta* Mulder and Trebilcock.
Fig. 3.—*Plumularia corrugatissima* Mulder and Trebilcock.
Fig. 4.—*Plumularia scabra* Lamarck.
Fig. 5.—*Plumularia scabra* Lamarck.
Fig. 6.—*Plumularia balei* Bartlett.
Fig. 7.—*Aglaophenia bakeri*, n. sp.
Fig. 8.—*Aglaophenia bakeri*, n. sp.

× 80.

[PROC. ROY. SOC. VICTORIA 31 (N.S.), PART II., 1919].

ART. XIII.—*Notes on Eucalypt Leaves occurring in the Tertiary Beds at Bulla.*

BY R. T. PATTON, B.Sc.

(With One Text Figure).

[Read 7th November, 1918].

The fossils occur in a fine mudstone beneath the newer basalt. These leaf beds were found by Mr. James, B.Sc., last year, and contain many other leaves besides those of Eucalypts. These leaves are small, narrow and pointed, which indicates rather adverse conditions of life. These leaves are too simple for any identification work. Besides the leaves, casts were found which appeared to be of a lycopodinaceous character, and other casts appeared to be those of crushed stems. The beds appear to have been laid down along the banks of the stream. The Eucalypt leaves appear to belong to one general type. We must bear in mind, when dealing with fossil Eucalypts, the wide variability of the genus at the present day, and although we cannot say whether this variability existed in geological times, still it must not be left out of account. It is recognised that to differentiate Eucalypts on herbarium material is often impossible.

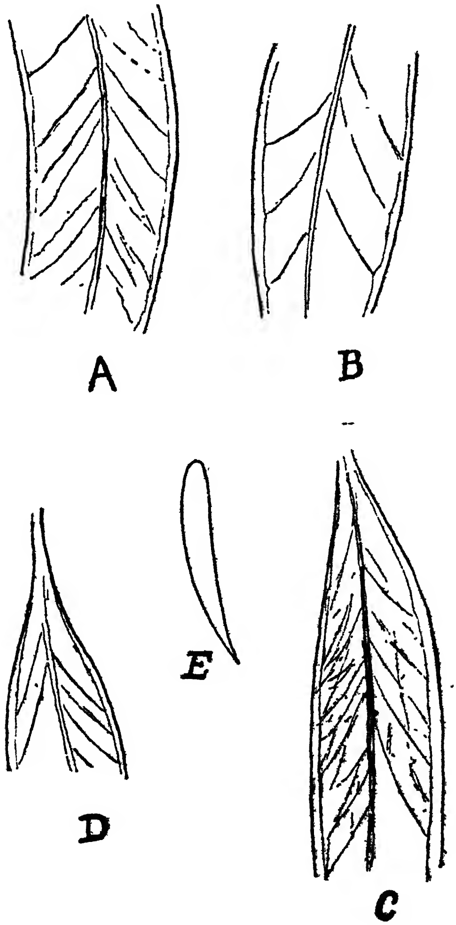
In the Geol. Survey Records, Vol. I., are given, by H Deane, M.A., some figures of fossil Eucalypt leaves from Berwick. Some of these do not possess sufficient differences to be classified as different species. These belong more or less to two general types of leaves. Eucalyptus prâecoriacea forms an exception. This is a very doubtful Eucalypt.

All of the leaves from Bulla belong to one general type. I do not think we are justified in making species out of material which all conforms to a general type.

The leaves are moderately broad, lanceolate and slightly falcate. The marginal vein is moderately removed from the edge, and is only slightly indented. The lateral veins diverge at an angle of about 50°, and are not widely distant apart. The leaf is approximately symmetrical. The margins gradually fade into the petiole and do not meet it abruptly.

Taking these casts generally they do not differ very much from those figured in Vol. I., Geological Survey Records. The Bulla leaves bear a resemblance to those of E. rostrata, which is found

growing along the river close by, and if the nodules found with the leaves be fruits the resemblance is still closer, but it would be unwise to suggest that the fossils are those of E. rostrata. These fossils give an insight into the evolution of the Eucalypts. The earliest stage, represented by the Bloodwoods, had been passed, but how far the genus had progressed it is impossible to say from these alone.



A, B, C, D—General type of fossil Eucalypt at Bulla.
E—A common leaf with the Eucalypt leaves.

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART II., 1919].

ART. XIV.—*Note on the Real Significance of the Michelson-Morley Experiment.*

By E. F. J. LOVE, M.A., D.Sc.

(University of Melbourne).

[Read 7th November, 1918].

In the year 1887, Michelson and Morley[1] published their well-known research having for its object the detection and measurement of the speed and direction of the earth's motion relative to the ether of space. The apparatus employed by them at the time was fully adequate to their purpose; as subsequently modified by Michelson,[2] it became capable of affording measurements of considerable precision; yet the result was uniformly null.

The obvious conclusion to draw was that the relative speed was zero; i.e., that the ether in the neighbourhood[3] of the earth is carried along with it in its orbital motion. The difficulty of such a conclusion lay in the fact that all other investigations, carried out up to that—or even the present—date, go to prove that the relative speed in question and the earth's orbital velocity are indistinguishable; in other words, that the earth's motion leaves the ether undisturbed.[4]

In 1892, Fitzgerald[5] and Lorentz[6] independently suggested their (now famous) "contraction hypothesis" as a way out of the difficulty. This asserts that a material body, when set in motion, undergoes a change of linear dimension in the direction of that motion. As the phenomena of electrolysis had already proved the mutual actions of atoms in the molecule to be, in part at least, electrical, the occurrence of *some* such change could hardly be disputed; it only needed recognition; but its sign and amount were alike undetermined by such phenomena as those of electrolysis. Fitzgerald and Lorentz accordingly suggested that the change might, for all that was known at the time, very well be a contraction, of the right amount to account for Michelson and

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1 Phil. Mag. [v.], xxiv., 1887, p. 449.

2 Am. Journ. Sci. [iv.], iii., 1897, p. 475. Many later writers seem to have overlooked this interesting paper.

3 The term "neighbourhood," as the paper quoted in note 2 shows, must be liberally interpreted.

4 Which is not quite the same thing as saying that the ether is at rest in space.

5 Nature, xlvi., 1892, p. 165.

6 Versl. d. k. akad. van Wet., 1892-3, p. 74.

Morley's negative result. Their discussion really proved that the Michelson-Morley experiment was not conclusive as to the relative motion in question; Michelson apparently accepted this point of view, as in his paper of 1897,[1] he specifies the hypotheses :—

(a) Independence of motion;

(b) The contraction hypothesis;

(c) Influence of the earth on the ether at the distance apparently required by his experiments,

as all about equally difficult to credit.

During the next ten years, Larmor and Lorentz, working independently, developed the mathematical consequences of a new electrodynamic theory, in which the atoms of matter were regarded as complexes of positive and negative electrons, capable of free motion, in a medium which that motion left undisturbed. Larmor[2] was the first to succeed in extending the computations of this theory to the second order of small quantities, and so to conclude—

(a) That the contraction posited by Fitzgerald and Lorentz would necessarily take place in matter constructed from such atoms.

(b) That its magnitude would be independent of the chemical nature of the moving matter.

(c) That this magnitude would be numerically equal to half the square of the astronomical Constant of Aberration; i.e., precisely that required to account for Michelson and Morley's results.

(d) That these results would consequently come into line with the positive results of other experiments as evidence for the equality, within the limits of experimental error, of the earth's orbital velocity with the relative velocity of the earth and the ether.

Larmor's result was often misunderstood at the time, as it was supposed—though quite erroneously[3]—to be dependent on his special theory of electronic structure; but its pertinence was something more than confirmed when Lorentz[4] proved that the contraction was not a mere second approximation, but an exact result of their electrodynamic theory.

In all probability these investigations would have been regarded as conclusive, but for the reluctance, long felt by chemists and physicists alike, to accept a purely electrodynamic theory of

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1 See note 2, *supra*.

2 Aether and Matter, pp. 173-176.

3 Larmor had actually anticipated (l.c., p. 86) and warned his readers against this misinterpretation of his general argument.

4 Proc. Amst. Acad. (English edition), vi., p. 809.

inertia. It was possibly owing to this reluctance that the experiments of Morley and Miller[1] which proved the null result of the Michelson-Morley experiment to be independent of the material of which the apparatus was constructed, were regarded more as a cause for wonder than as—what they really were—a brilliant conformation of Larmor's predictions

Times have changed. Owing to researches such as those in which Thomson, the Curie's and Rutherford were pioneers—researches far removed from the domain of experimental optics—the electron theory of atomic constitution may be regarded as firmly established, quite as much so as the atomic theory itself. This being the case, we are entitled to assume it as the basis of argument, instead of its conclusion. Under these conditions, the occurrence of the Fitzgerald-Lorentz contraction is no longer a hypothesis, but an immediate deduction from our theory of matter. The Michelson-Morley experiment, combined with this deduction, then takes its rightful place among the evidences for the relative independence of material and etherial motion—a place of pre-eminence, as it is the only experiment on the subject yet designed, much less completed, in which quantities of the second order of smallness are involved in measurable fashion. This, then, we take to be its real significance; it is a valuable piece of evidence, perhaps the most valuable we have, in favour of the very theory which it was at first supposed to have disproved.

If this idea be correct, it is important to notice that it holds good independently of all questions as to the relation between the Lorentzian electrodynamics and modern relativity doctrines. Whether the Principle of Relativity be the expression of a profound physical truth or a brilliant mathematical speculation, the significance of Michelson and Morley's result, as a demonstration of the independence of the motion of the earth and ether, remains the same.

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1 Phil. Mag. [vi.], ix., 1905, p. 680.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919].

Art. XV.—*Contributions to the Flora of Australia, No. 27.*

By ALFRED J. EWART, D.Sc., Ph.D.

(Government Botanist of Victoria and Professor of Botany and Plant Physiology in the Melbourne University).

(With Plate XVIII.)

[Read 7th November, 1918].

In connection with the work of the Plant Names Committee, and also owing to the issue of Mr. Maiden's "Census of New South Wales Plants," it has been necessary to investigate the scientific names in use for a number of Victorian Plants. In most cases it was a question of which of two names had priority, but in a few cases doubt had arisen as to whether a plant recorded as Victorian was really a native of Victoria or not. The decision arrived at is given in the following pages, with a reference to the evidence where it seemed necessary to give it.

In addition at the end of the present paper some observations on the growth in girth of the Elm are recorded.

Acacia buxifolia, A. Cunn. (A. lunata, Sieb.). (Leguminosae). "Box Leaf Acacia."

Acacia linifolia, Willd. "Flax Acacia."

The question has been raised as to whether this plant is really a native of Victoria. The Herbarium contains specimen collected in Gippsland, Victoria, by Mr. Howitt in 1884.

Acacia longifolia, Willd. "Sallow Acacia."

The following plants formerly classed as varieties, namely, Acacia mucronata, Wild., A. Sophorae, R.Br., and A. floribunda, Sieb., have been again raised by Mr. Maiden to specific rank. The matter is rather one of convenience and personal judgment than of scientific investigation, and hence for uniformity these plants may be recognised as three additional species to the list of Victorian Acacias.

Acacia salicina, Lindl., var. varians. "Willow Acacia."

Black states that this variety should be found near the Murray. So far no Victorian specimens of it have been found.

ACACIA SUBTILINERVIS, F. v. M. (Leguminosae). "Eastern Acacia."

This plant was recorded as Victorian by Baron von Mueller. The nearest locality is from Mt. Inley, N.S. Wales. It must therefore be deleted from the Victorian Flora.

ALHAGI CAMELORUM, Fisch. (Leguminosae). "Camel Thorn."

Rutherglen, G. H. Adcock, F.L.S., 10/1/1918. A native of Central Asia and the Orient.

This is the first record of this plant as growing wild in Victoria. The plant grows luxuriantly near the Murdering Hut Creek, and on the spoil of a dam near McInerney's, about three miles away. It first appeared about two or three years ago, and was then cut down.

ALYSICARPUS VAGINALIS, D.C. (Fabricia nummulariaefolia, Ktz.). (Leguminosae).

Darwin, Dr. Gilruth, 1918.

This plant was recorded from North Australia, generally without any previous record attaching it to a definite locality in the Northern Territory. It appears to be common, and Dr. Gilruth informs me that it is a valuable fodder plant, carrying particularly in the wet season more stock than anything else. All stock are extremely fond of it, especially in the pre-flowering stage, but even when ripe and the stem somewhat woody it is eaten with avidity.

A. vaginalis is a polymorphic species common in the old world Tropics, and it has also become naturalized in America, but little or no attention appears to have been paid to its economic possibilities as a pasture plant for warm climates.

ALYSSUM LINIFOLIUM, Stevens (A. minimum, Pallas). (Cruciferae). "Desert Alyssum."

APHANOPETALUM. This genus is transferred from the Saxifragaceae to the Cunoniaceae.

BORONIA INORNATA, Turcz., Bull. Soc. Nat. Mos., xxv., 1852, 11, 164, replaces BORONIA CLAVELLIFOLIUM, F. v. M., Trans. Phil. Soc. Vict., 1, 1855, p. 12.

BRAZENIA SCHREBERI, Gmel. (Nymphacaceae). "Water Shield."

Syst. 853 (B. purpurea, Casp. Journ. Sc. Acad. List IV., 1873-4.)

CALLISTEMON LINEARIS, D.C. (Myrtaceae).

As no Victorian specimens of this species are known it must be deleted from the Victorian Flora.

CALLISTEMON RUGULOSUS, D.C. (1829). (Myrtaceae).

This name replaces that of C. coccineus, F. v. M., 1859.

CALLISTEMON SIEBERI, D.C. (1828).

The question has arisen as to whether C. pithyoides, Miquel, is not a form of the same species. The two plants have, however, a very different external "facies," and the latter has hairs on the stem and young leaves, more scattered fruits, narrower leaves with a different internal structure. Hence both species must stand.

CALOCHILUS HOLTZEI, F. v. M. (Orchidaceae).

Near Darwin, Nth. Australia, M. Holtze. 1892.

This plant is recorded in the Victorian Naturalist, March, 1892, and was inadvertently omitted from the Flora of the Northern Territory.

CALTHA INTROLOBA, F. v. M., and CALTHA NOVAE ZEALANDIAE, Hook. (Ranunculaceae).

Mueller apparently included under the former species the latter one also. Both names stand as valid species. C. introloba has white flowers which are larger than the yellow flowers of C. Novae Zealandicae. Hill (Annals of Botany, 1918, p. 421) distinguishes the former species by the leaf appendages being folded at an angle of 45°C to the petiole, and in the latter being folded at right angles to the petiole.

CAPPARIS MITCHELLII, Lind. (Capparideae). "Desert Caper."

This name has been variously spelt with one or two terminal i's. In the original description in Mitchell's Expedition it is spelt as above.

CARDAMINE TENUIFOLIA, Hook. (Cruciferae).

Journal of Botany, I., 1834, 247.

This is given as a variety of C. hirsuta, L., by F. v. Mueller, Census I., 1882. It appears to be a valid species.

CASSYTHA MELANTHA, R. Br. (Lauraceae). "Large Dodder Laurel"

Prolonged search during more than one season failed to discover any plants of this parasite or of C. glabella showing any rooted attachment to the ground. Mr. Semmens, Forester at Bendigo, also informs me that he has never been able to find a seedling of Cassytha attached to the ground. The possibility, therefore, existed that these species were like Cuscuta, the ordinary Dodder, rootless, and developed directly on the host plant. The fruits of C. melantha are large, and with a very viscid pulp which sticks readily to the stems of the host plants. The thin walled pulp cells contain numerous granules of a viscid material which later, as the pulp cells break down, give them their sticky nature.

A quantity of ripe fruits of C. melantha were collected in autumn in order to germinate them. They were planted with and without the pulp on the surface and at varying depths. None germinated. The outer coat is very hard, and it was found that to produce germination it was necessary to file the seed coats. Such seeds germinated in spring (September to October), and their development was traced up to the point of attachment of the host plant.

The radicle escapes first, at once bends downwards and forms a few simple roots. (Pl. XVIII., Figs. a, b, c.) The other end of the rod-like embryo remains in the seed, absorbing food materials from the endosperm, and growth in length takes place from the tip embedded in the seed to form a strongly arched stem, thick at the base and tapering towards the apex. If the seed is deeply buried it does not appear above the surface; but if near the surface it is raised upwards by the straightening of the bent portion, and not by the elongation of the straight basal portion. When the endosperm has been absorbed, the absorbent apex of the stem shakes off the seeds and escapes, the last scale leaves being developed while still in the seed. (Pl. XVIII., Fig. j.). No cotyledons are developed. The first scale leaf is from 2 to 3½ inches from the base of the stem. If the stem is cut above it, a lateral shoot

develops in the axil of the scale leaf (Fig. m). If the stem is killed from a point below the first scale leaf, the basal part remains living for weeks, increases in diameter, but ultimately the roots die and the thick basal green shoot follows suit. (Fig. h). In one such case after persisting for three months a crop of witches' broom-like outgrowths formed at the apex, one of which developed into a slender twining shoot. (Fig. n). The seedlings of C. melantha therefore resemble those of *Cuscuta* in having no cotyledons, but differ in having an early rooted stage. After a good parasitic attachment has been formed the basal part shrivels and dies. In one respect the germination is quite peculiar, namely, in the fact that the *apex of the stem* is the absorbing organ, and remains in the seed until all the food material has been absorbed, usually developing scale leaves in the seed before it is finally withdrawn. In this respect the germination of *Cassytha melantha* is unique, and it would be of interest to know whether all the species of *Cassytha* behave similarly, and also whether they are all devoid of cotyledons.

CASUARINA STRICTA, Ait., replaces CASUARINA QUADRIVALVIS, Labill. (1806). (Casuarineae).

It is to be regretted that the well-known name of C. quadrivalvis must go, but there seems to be no other course possible. The same change has been made by Mr. Maiden. (Fl. N.S. Wales, II., 142.)

COPROSMA REPENS, Hook. f. (Rubiaceae).

The question of the relationship of this plant to Coprosma pumila, Hook, f., has been raised. Both names really refer to the same plant. The former name was first given in Hooker's Flora Antarctica, I., 22, p. 16. In the appendix (Flora Antarctica, II., 542), the name of C. pumila is given but really refers to the same plant, hence the former name stands. In Hooker's Flora of New Zealand, C. pumila is quoted from Hook, Flora Antarctica, I., p. 22, and C. repens from I., p. 23; but the quotations are incorrect. C. repens is on p. 22, and C. pumila is only mentioned in the appendix.

DIDISCUS PILOSUS, Sm., replaces DIDISCUS PUSILLUS, F. v. M., and DIDISCUS BENTHAMI, Domin., replaces D. PILOSUS, Benth.

DIDYMOTHECA PLEIOCOCCA, F. v. M. (Phytolaccaceae), now becomes GYROSTEMON CYCLOTHECA, R. Br.

DODONAEA VISCOSA, L. (Sapindaceae). "Giant Hop-Bush."

The question has arisen as to whether the variety spathulata of this species is not sufficiently distinct to be recognized as a distinct species. If so, at least four other varieties, namely, angustifolia, asplenifolia, attenuata, and cuneata would need corresponding specific recognition. Although the extreme forms look very distinct, all grades of transition occur between these varieties, and it is evident that we are dealing with a plant in which the segregation of a plant into a well marked species adapted to different habitats is taking place, but is not yet completed. In a century or two botanists may be justified in recognizing all five species.

DYSPHANIA.

This genus has been tranferred from the Chenopodiaceae to the Caryophyllaceae, with which it appears to have a closer affinity.

ELEUSINE INDICA, Gaertn. (Gramineae). "Indian Eleusine"

Matarauca, VII., Dr. J. A. Gilruth. 1918. "Like Paspalum, eaten very readily by stock."

This grass is native to New South Wales and Queensland, but is a new record for the Northern Territory. Like immature Sorghum it contains a cyanogenetic glucoside yielding hydrocyanic acid, when macerated in water or eaten by stock, and hence capable of poisoning or injuring the latter when eaten in quantity.

ERIOSTEMON AMPLIFOLIUS, F. v. M. (Phebalium amplifolium), nomen nudum.

This plant was described by Baron von Mueller in 1884, in the Melbourne Chemist and Druggist, Dec., 1884, as follows:—

"Collected by C. M. Walter."

"Eriostemon amplifolius, F. v. M. It has very large, flat, broadly ovate or somewhat rhomboid leaves of rather thick texture and of slightly purplish hue, more frequent in the genus Boronia than in Eriostemon. Neither flowers or fruit were found." No locality is given, but the previous species described, Eriostemon Coxii, is from the Murrumbidgee, N.S. Wales. There are no specimens of E. amplifolium in the National Herbarium, and no trace of this species can be found. The description is so

incomplete that even if the species actually exists and were refound it would be impossible to identify it with certainty with the above named, which must therefore be regarded as a permanent nomen nudum and deleted from the list of Australian Plants.

EUCALYPTUS CORIACEA, A. Cunn., replaces E. PAUCIFLORA, Sieb., see Maiden's Fl. of N.S.W., vol. ii., 117.

EUCALYPTUS DIVERSIFOLIA, Bonpl., replaces E. SANTALIFOLIA, F.v. M.

EUCALYPTUS FRUTICETORUM, F. v. M., replaces E. POLYBRACTEA, R.T.B., see Maiden's Fl. of N.S.W., v., 27.

EUCALYPTUS RADIATA, Sieb. (E. AMYGDALINA, var. RADIATA).

This variety was at one time raised to specific rank as E. numerosa, Maiden, but Mr. Maiden now suppresses his own name in favour of the above. (See Maiden's Fl. of New South Wales, II., p. 147.)

EUCRYPHIA.

This genus is transferred from the Saxifragaceae to the Eucryphiaceae, but the genus Bauera remains in the Saxifragaceae.

GAILLARDIA PULCHELLA, Fouger. (Compositae). "Painted Gaillardia."

Mildura, C. French, junr., November, 1917.

A native of North America, apparently an escape from cultivation, and appearing in hundreds in the Mildura district.

GYROSTEMON COTINIFOLIUS, Desf., stands in place of CODONOCARPUS COTINIFOLIUS, F. v. M.

HEDYCARIA CUNNINGHAMI, Tul. (1855) is replaced by H. ANGUSTIFOLIA, Cunn. (1838), which is the older name. The former name was adopted by F. v. Mueller, and has been locally used; the latter name was used by Bentham.

IXIA LUTEA, Baker. (Irideae). "Yellow Corn Lily."

Avoca, Vic., per J. Callander. October, 1917.

A garden escape, spreading in the Avoca district.

Koeleria phleoides, var. azorensis, Domin. (Gramineae).

St. Eloy D'Alton, Dimboola, 1917.

A depauperate specimen of a variety recently described, not previously recorded from Victoria, and probably introduced. The variety differs from the type in having hairy glumes, and being more stunted in all respects. The grass was identified by Professor Hitchcock, Agrostologist to the United States of America.

Lepidium rotundum, D.C. (Cruciferae). "Veined Pepperwort" (Lepidium phlebopetalum, F. v. M.).

Loranthus miraculosus, Miq. (Loranthaceae).

Bentham gives this as L. pendulus, var. parviflora, but Mr. Maiden, in the Census of New South Wales Plants, 1916, raises it to specific rank. Although the differences from L. pendulus are not very great (smaller leaves and flowers and the latter often 4-partite, etc.), the plant seems to form a constant and well marked type, with a facies distinct from L. pendulus. Miquel, in Plantae Preissianae, I., p. 281, 1844-5, quotes a species, No. 6, under a manuscript name of Lehmanns', as L Melaleucae, which is the same as the following species, No. 7, L. miraculosus, and strict priority rule requires that the earlier name should stand. Lehmann, as editor of the work, presumably consented to the publication of the M.S. name, but as the whole article on Loranthaceae is by Miquel, it would seem to be more appropriate to retain his own name for the species, namely, L. miraculosus.

Martynia fragrans, Lindl. (Pedalineae). "Fragant Martynia."

Yalca, J. McKenzie, Esq., April, 1918. Probably a garden escape. This is its first appearance in Victoria as growing wild.

Myriophyllum propinquum, A. Cunn. (1839), is replaced by Myriophyllum intermedum, D.C. (1828), the older name.

Olearia glutinosa, Benth. (Compositae). "Swamp Aster."

The question has been raised as to whether the varieties *glutescens* and *oraria*, which were raised to specific rank by F. v.

Mueller are not really distinct species. It seems, however, to be impossible to form any satisfactory line of demarcation between these varieties and O. glutinosa.

PIMELEA PUNICEA, R.Br., var. BREVILOBA. (Thymelacaceae). "Purple-weed."

Daly River Farm, J. R. Coney, Esq., Manager, per Dr. Gilruth.

This plant is said to be poisonous to stock, which will only eat it when cut up with other herbage. The plant is recorded in the Flora of the Northern Territory, pp. 197, 285 as being poisonous, but as in the case of some other species suspected of poisonous properties, the poisonous principle has not been extracted and determined, and the nature of the poisonous action is uncertain. As all Pimeleas contain strong, tough fibre, the possibility of a mechanical action must always be taken into consideration.

SELAGO CORYMBOSA, L. (Scrophulariaceae). "Selage or Waterfinder."

Bairnsdale, Vic., per G. Renner, Esq., March, 1918.

This plant has not been previously collected in Victoria. It is a native of South Africa.

SPYRIDIUM ERIOCEPHALUM, Fenzl., and S. VEXILLIFERUM, Reissk.

A question of the synonomy of these two species arose, but on investigation both appeared to be distinct.

THRYPTOMENE ERICAEA, F. v. M. (Myrtaceae).

This plant appears to be confined to South Australia, and hence must be deleted from the Victorian Flora.

TRIGLOCHIN.

Ostenfeld, in Dansk Botanish Arkiv, 1918, 30, gives a revision of the annual species of Triglochin and recognizes the following :—

Triglochin calcitrapa, Hook. Vic., T., S.A., W.A., N.S.W., Q.
,, Stowardi, N. E. Brown. W.A.
,, turrifera, Ewart. Vic.
,, centrocarpa, Hook. All six States.
,, minutissima, F. v. M. V., S.A., W.A.
,, tricophora, Nees. W.A.
,, Muelleri, Buchenau. W.A.

Ostenfeld also gives a key to the annual species. Including the perennial species, the following would be the key as modified to include all the Australian species of Triglochin at present recognized.

ANNUALS.

I.—Fruits of three nutlets falling from a central axis.

A. Carpels with free apex, the three fertile ones with a reflexed apical mucro; fruit turbinate - - *T. mucronata*

B. Carpels united up to apex, no apical mucro, fruit linear or pyramidal to ovoid.

(a) Carpels with well developed, mostly incurved basal spurs; fruit linear-pyramidal or pyramidal.

(b) Fruit linear-pyramidal, evenly tapering from base towards apex; basal spurs incurved.

1. Fruit 7 mm. long, with rather large basal spurs - - - - - *T. calcitrapa*

2. Fruit about 15 mm. long, basal spurs comparatively small - - - *T. Stowardii*

Fruit pyramidal with conical apex, 3.5–4 mm. long; basal spurs not incurved - - - - - *T. turrifera*

(B) Carpels with very short or hardly any basal spurs; fruit linear to elliptic or ovoid.

(a) Fruit linear or linear-pyramidal.

1. Fruit mostly linear-pyramidal, 2-4 (rarely 5.5) mm. long; carpels with slightly dilated base and very short, but mostly distinct basal spurs - - - *T. centrocarpa*

2. Fruit linear, 1-1.5 mm. long; carpels with hardly any dilation at the base and no spurs *T. minutissima*

Fruit oblong to elliptic or ovoid.

1. Fruit oblong-ovoid, 2-2.5 mm. long, tapering into a conical apex very short, but distinct basal spurs - - - - - *T. trichophora*

2. Fruit elliptic, about 2 mm. long, without any distinct apical part; no basal spurs - *F. Muelleri*

PERENNIALS.

Plants 2 inches to a foot in height - - - - *T. striata*

II.—Fruit of 3 to 6 nutlets not leaving a central axis or sterile partitions.

1. Flowers nearly sessile, carpels usually six - *T. procera*

2. Flowers sessile, carpels usually two or three *T. Maundi*

WITHANIA SOMNIFERA, Dun. (Solanaceae). "Narcotic Winter Cherry."

Black Rock, Burnley, Elsternwick, and Domain (South Yarra). J. W. Audas, 15/5/1918.

This introduced plant is already widely spread and has now sufficiently established itself to be considered a naturalized alien. Its creeping roots are difficult to eradicate, and it has slight poisonous properties, which would tend to cause abortion. It is native to the Mediterranean Regions and Africa.

ULMUS CAMPESTRIS, L. "Common Elm."

(*Rate of Growth*).

The growth in circumference of a fine tree standing in the Herbarium grounds was followed over a year. A smooth surface was prepared on a horizonal line, 5 ft. 6 in. from the ground, and the measurement taken with a tape. The circumference was 6 ft. 10 in., and no growth was shown from July until the end of October. Growth began in November, but even at the middle of December the increase barely exceeded a quarter of an inch. The main growth took place from the middle of December to the end of February, and amounted to 1¼ inches. The circumference was then 6 ft. 11.5 in. It remained stationary until March, but at the beginning of April had decreased by 0.2 of an inch, and at the end of April by 0.3 inch. Probably this contraction is due to the cambium layers being no longer so highly distended as when actually growing. From April to June the circumference remained constant at 6 ft. 11.2 in.[1]

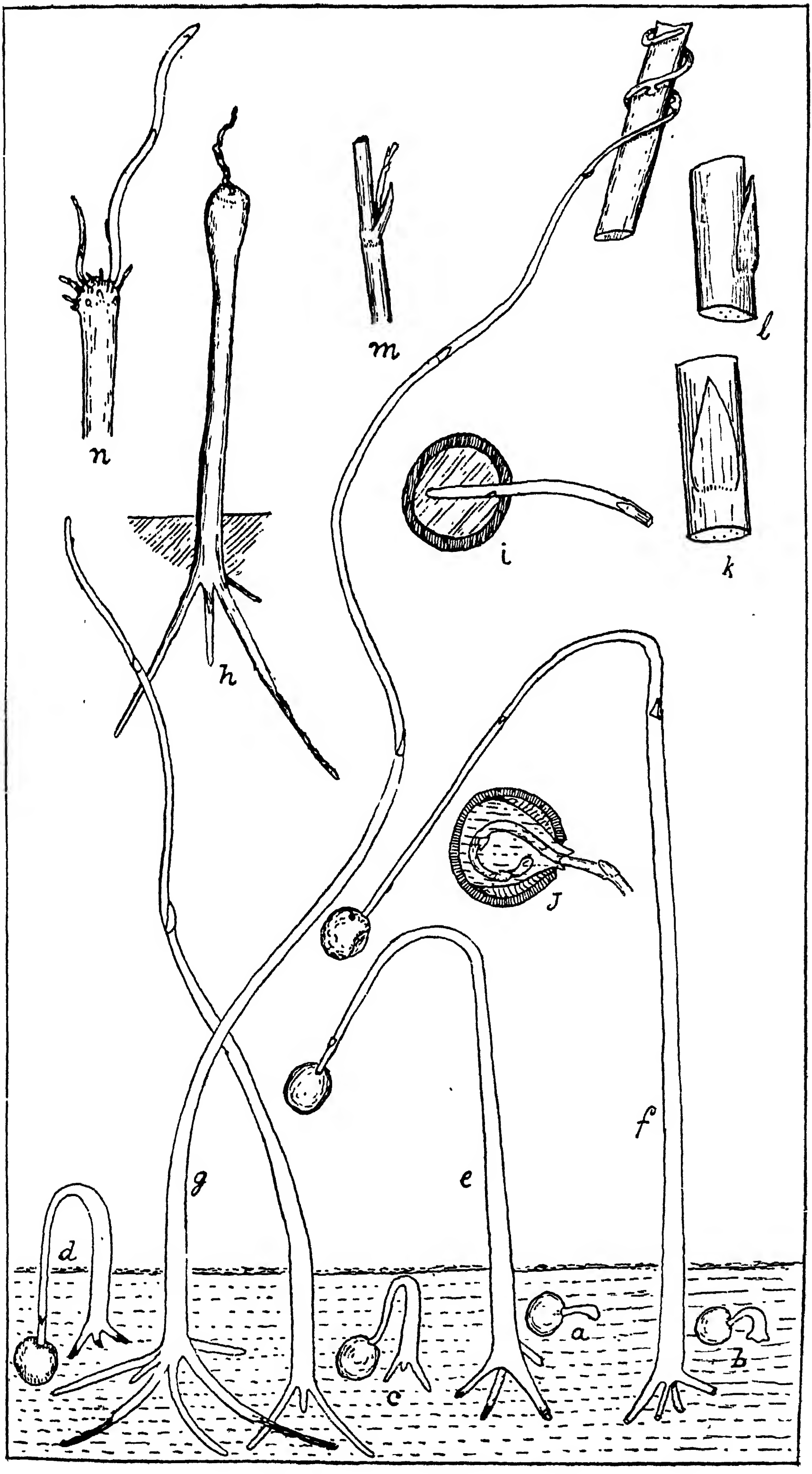
A boring taken of the tree from which sections were made showed that the cambial growth began nearly a month before any apparent increase in external girth was shown. Evidently the bark only begins to expand externally when the internal growing tissues have produced a sufficient internal pressure upon it, and the increasing pressure at first pushes the bark obliquely into cracks or spaces previously developed. It is only when a certain amount of cambial growth has taken place that the outermost portions of an irregular scaly layer of bark move outward as a whole, increasing the external diameter of the tree.

1 The measurements were made by a tape under constant tension checked against a wooden scale.

EXPLANATION OF PLATE XVIII.

Cassytha melantha.

a, b, c, d, e, f, stages in germination.
g, plant forming first parasitic attachment.
h, plant with apex killed from beneath first scale leaf.
i, apex of stem absorbing endosperm.
j, apex of stem about to escape from seed.
k and l, first and second scale leaves.
m, shoot developing in first scale leaf after removal of apex of stem.
n, decapitated stem, forming new shoots.


n
h
m
l
i
k
j
f
e
g
d
c
a
b

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART II., 1919].

ART. XVI.—*On the Synthesis of Sugars from Formaldehyde, Carbon Dioxide and Water.*

BY ALFRED J. EWART, D.Sc., PH.D.

(Government Botanist and Professor of Botany and Plant Physiology in Melbourne University).

[Read 7th November, 1918].

In the Proceedings of the Royal Society of Victoria, Vol. 30, 1918, p. 200, a method was described of producing sugar from formaldehyde by the joint action of boiling lime water and sodium hydrate on formaldehyde. In the earlier experiments the by-products were mainly calcium tartrate and sodium formate. In later experiments the by-products were calcium carbonate and calcium and sodium formates. The formaldehyde first used was a sample of Merck's, purchased before the outbreak of war, and used in preference because of its supposed greater purity. It seems probable, however, that the appearance of tartaric acid was due to the formaldehyde having undergone slow oxidation prior to use, possibly in the presence of a trace of some metallic or other oxidase, or of some accidental contamination. It is well known that nitric acid, for instance, will slowly oxidize ordinary aldehyde (acetaldehyde) to glyoxal, from which tartaric acid is readily synthesized, as for instance by the addition of hydrocyanic acid, and subsequent treatment with dilute mineral acid. Tartaric acid is also readily oxidized to formic acid, and hence the reaction might be reversible. Attempts to synthesize tartaric acid from formic acid by passing CO_2 into a boiling solution of a formate containing reducing agents (powdered Mg.) and oxidizing agents (H_2O_2, HNO_3), failed, as was also the case when formates, Mg, CO_2 and water were kept under pressure for long periods of time.

Similarly formaldehyde subjected to the slow and rapid action of a variety of oxidizing agents at varying temperatures (HNO_3, H_2O_2, $K_2Cr_2O_2$, K_4Cfy, K_3Cfy, etc.), failed to yield any tartaric acid when used for sugar synthesis. The statements made in the note first published must therefore be modified in two respects, namely: no tartrates are produced, and the resultant liquid is optically inactive instead of showing a slight optical activity.

The purpose of the present work was to determine the best condition for the synthesis of sugars from formaldehyde and to obtain

a comprehensive view of the different agencies by which such synthesis could be brought about, and the relationship between them. In the first instance the action was tested of alkaline metallic hydroxides and carbonates, and then of non-metallic alkalies.

Alkaline metallic hydroxides.

Caustic Soda. If strong caustic soda is run into boiling 40 % formaldehyde until the liquid ceases to smell of the latter, sodium formate is produced, but no reducing sugar. If 30 c.c. of 40 % CH_2O and 14 c.c. of 33 % NaHO are boiled to dryness in a flask with a narrow outlet, the residue consists of nearly pure sodium formate, only a trace of matter is removed by alcohol, and this contains no reducing sugar.

If, however, while the evaporation is going on, hot water is added several times, the residue contains a small trace of reducing sugar removed by washing with 96 to 98 % alcohol.

If 30 c.c. of 40 % CH_2O are added to 500 c.c. of water and 40 c.c. of 10 % NaHO, and the bulk of the liquid dripped slowly into a boiling portion, the liquid continues to smell of CH_2O until nearly dry, and the pale yellow residue contains an appreciable amount of reducing sugar but consists mainly of sodium formate.

If more soda is added during boiling all the CH_2O disappears, and the amount of reducing sugar is increased, but any excess of soda turns the liquid dark brown.

Further experiments showed that with increasing dilution the proportion of sugar to sodium formate increased, but that the latter was always formed in excess.

Lime-water.—100 c.c. of Lime-water were added to 25 c.c. of 40 % formaldehyde, and while boiling in a flask fitted with a condensing arrangement, lime-water was run in slowly until all the CH_2O was used up. Approximately, 1 litre of lime-water was required. The pale yellow syrup yielded calcium formate when evaporated, methyl alcohol escaped, and the gummy residue contained a high proportion of reducing sugar, largely pentose and giving the phloroglucin reaction readily. The amount of sugar was considerably less than with the joint action of sodium hydrate and calcium hydrate as previously described.

Barium and Strontium hydrates.—With Barium hydrate, to complete the reaction an excess of the alkali is required and prolonged boiling. Strontium hydrate is more active, only a slight excess is necessary, and moderately prolonged boiling (2-4 hours

with 5 grains of $Sr\,H_2O_2$, 25 c.c., 40 % CH_2O and 500 c.c. water). Soluble Barium and Strontium formates are produced, and the reducing sugars contain a high proportion of a pentose sugar resembling arabinoketose, and less soluble in 95 % alcohol than the hexoses.

Magnesium hydrate.—To complete the reaction an excess is required, and either 2 days' heating on a water bath, or 4 to 6 hours' boiling. Magnesium formate is produced, and the reducing sugars give an abundant precipitate of golden yellow needles with phenylhydrazin. Most of these resembled the bundles produced with arabinoketose, but a smaller proportion appeared to correspond to a glucosazone.

Ammonium hydrate.—Ammonia directly combines with formaldehyde to form urotropin. If magnesium powder is added, ammonia slowly escapes, formaldehyde reappears, and magnesium formate is slowly formed, and the residue is black instead of white. After 3 months at 12° C., the filtered liquid blackens with sulphuric acid, but contains no reducing sugar. The formaldehyde present is, however, partly converted into reducing sugar by prolonged boiling with Magnesium hydrate.

This observation shows that the Magnesium of chlorophyll might be able to liberate formaldehyde from a non-volatile temporary storage combination for subsequent polymerization to sugar.

Alkaline carbonates.—If 10 % Na_2CO_3 is dripped slowly into boiling 5 % CH_2O, the reaction lags considerably, and an excess of Na_2CO_3 is always present by the time all the CH_2O has disappeared. This causes the syrup to turn brown. Using 2 grams of $Na_2\,CO_3$ to 20 c.c. of 40 % CH_2O and 200 c.c. of water, the reaction was completed after 2 hours' boiling. Using 0.5 grams of Na_2CO_3, prolonged boiling was needed to complete the reaction, and a small trace of Na_2CO_3 still remained; less sugar was formed.

The addition of absolute alcohol to the syrup precipitates the sodium carbonate remaining, and a second addition of alcohol after concentrating to a small bulk precipitates nearly all the sodium formate. A second repetition leaves a solution of a nearly pure mixture of reducing sugars, containing both pentoses and hexoses.

Potassium carbonate acts similarly to sodium carbonate, but is much less active, prolonged boiling being necessary, with an excess of the carbonate. The bi-carbonate is still less active, but the products are the same, namely, sodium formate, methyl alcohol, and reducing sugars.

Calcium carbonate.—H. and A. Euler (Ber. d. D. Bot. Ges., 1906, 39, pp. 36 and 39), have shown that when 2 % formaldehyde is heated with calcium carbonate, a pentose sugar, arabinoketose is formed, together with small amounts of glycollic aldehyde and dihydroxyacetone.

The calcium carbonate is converted into calcium formate, and the reaction is possible because a portion of the former exists in solution as calcium hydrate. As this is converted into formate CO_2 escapes and more chalk dissociates. Hence the rapidity of the action depends upon the fineness of division of the chalk. Thus using 5 c.c. of 40 % CH_2O to 250 c.c. water, and a slight excess of chalk, the following were the times taken for the removal of all the formaldehyde:—

Finely divided, freshly pptd. chalk, 70 hours' boiling.

Coarser portion of precipitate, 82 hours' boiling.

Dried precipitated chalk, 96 hours' boiling.

In all cases the liquid is pale yellow by the second day, and is distinctly browned by the time the reaction is completed. Presumably this is due to the presence of traces of dissociated lime caramelizing the sugar produced.

The syrup was evaporated to a small bulk, filtered, diluted and kept for 3 days at 30°C. (a) with dry yeast, (b) with fresh yeast and Pasteur's ash. Bacteria became abundant in (b). Both liquids yielded a distillate which gave the iodoform test for alcohol faintly but distinctly, but which did not contain sufficient alcohol to affect the boiling point appreciably. Evidently, however, traces of hexose sugars, fermentable by yeast, are formed in addition to arabinoketose.

Magnesium carbonate is feebly alkaline, more soluble, and dissociates more readily than calcium carbonate in solution. Hence it reacts more rapidly. Using half a gram to 5 c.c. of 40 % CH_2O and 250 c.c. of water, the reaction was completed in 4 hours boiling with magnesia alba levis, and in 12 hours with magnesia alba ponderosa.

Barium carbonate.—Using a slight excess of the solid and 5 c.c. of 40 % formadehyde the reaction was completed—

With 400 c.c. of water in 16 hours' boiling.

With 250 c.c. of water in 36 hours' boiling.

The sugars appeared to be the same as with calcium carbonate, but possibly owing to the difficulty of separating all traces of the poisonous barium formate even by the use of sulphuric acid, the tests with yeast were inconclusive.

Strontium carbonate.—Using 5 c.c. of 40 % CH_2O to 250 c.c. of water the reaction was completed with—

Freshly precipitated carbonate in 52 hours' boiling.
Ppt. dried, and then powdered, in 130 hours' boiling.
Large excess of fresh precipitate, in 30 hours' boiling.

The explanation is that the large excess contains more finely divided particles, which dissolve and dissociate more rapidly, and hence the rapidity of the reaction is greater. With similar materials there is, in fact, a relation between the solubility and the rates of reaction of calcium, barium and strontium carbonates with formaldehyde.

	$CaCO_3$.	$SrCO_3$.	$BaCO_3$.
Solubility in boiling water	18	53	66
Hours boiling required to complete reaction	70	52	36
Ratio of products	12	27	23

The barium and strontium carbonates are, however, not only more soluble, but about twice as chemically active as calcium carbonate.

Sodium formate is itself feebly alkaline. Hence the effect of boiling it with formaldehyde solutions of varying strengths was tried. The sodium formate was added directly, or a small amount at a time, and at atmospheric pressure and under pressures up to 15 atmospheres. In no case was any sugar produced. Potassium formate also gave negative results. Apparently the polymerization of sugar from formaldehyde is not induced merely by boiling in an alkaline solution, but requires also the presence of an alkaline base capable of combining with formic acid as fast as it is formed.

Sodium phosphate.—Na_3PO_4. After boiling 1 % formaldehyde with strongly alkaline 5 % sodium phosphate for 3 days, the liquid became almost neutral, was pale brown in colour, and contained a small quantity of reducing sugar. Apparently the alkaline sodium phosphate forms Na_2HPO_4, and the free soda produces sodium formate and polymerizes a little of the formaldehyde.

Non-metallic alkalies.—These are also capable of inducing the polymerization of formaldehyde to sugar.

Trimethylamine is strongly alkaline. 5 c.c. of 40 % CH_2O were boiled with 8 c.c. of Trimethylamine and 400 c.c. of water for 50 hours in a condensing flask, and the pale brown liquid evaporated to dryness. The residue was extracted with water, again boiled to dryness, and extracted with absolute alcohol. The latter left a

gummy residue of reducing sugar, apparently mainly or wholly pentose.

Aniline water is feebly alkaline. It gives a dense white precipitate with formaldehyde in concentrations down to 0.05 %. The white ppt. formed by adding 500 c.c. of saturated aniline water to 50 c.c. of 1 % formaldehyde smells of the latter even after 3 days' boiling. On evaporating to dryness and extracting the resinous residue (which is probably an analogous compound to Bakelite), with water, a trace of reducing pentose sugar was obtained.

The joint action of alkalies.

Since a mixture of caustic soda and lime appears to be more effective in polymerizing formaldehyde to sugar than either singly, it seemed worth while to try the effect of lime produced directly in the boiling formaldehyde. A preliminary experiment performed by added 5 % caustic soda to 250 c.c. of boiling 1.6 % formaldehyde containing in one case 0.8 % calcium chloride, and in the other no calcium chloride showed that all the formaldehyde was converted into formates and sugar in the first case with an addition of 13 c.c. of sodium hydrate, and in the other of 24.5 c.c., while the amount of sugar formed was approximately three times greater in the former case. The other products were calcium formate and sodium chloride.

To determine the best concentration for the reaction, 5 c.c. of 40 % formaldehyde and 5 c.c. of 17 % calcium chloride (anhydrous) were added to varying amounts of water, and 3.5 % sodium hydrate run into the boiling mixture until the reaction was completed.

Amount of Water present.		Amount of 3.5 % NaHO required.
35 c.c.	-	11.8 c.c.
60 c.c.	-	9.9 c.c.
110 c.c.	-	8.7 c.c.
260 c.c.	-	8.0 c.c.
510 c.c.	-	9.8 c.c.
760 c.c.	-	10.2 c.c.
1010 c.c.	-	11.4 c.c.

The concentration represented by the addition of 250 c.c. appears to be the best.

Hence using 5 c.c of 40 % formaldehyde in 250 c.c., and adding varying amounts of Calcium chloride, the amounts of caustic soda required to complete the reaction were :—

	Amount of 3.5% Caustic Soda required.
With 17% calcium chloride—	
0.0 c.c.	21.2 c.c.
2.0 c.c.	11.3 c.c.
3.0 c.c.	10.8 c.c.
4.0 c.c.	8.9 c.c.
5 0 c.c.	8.0 c.c.
8 0 c.c.	9.0 c.c.
10.0 c.c.	9.5 c.c.
With 15% NaCl—	
5.0 c.c.	20.8 c.c.
Solution saturated with NaCl.	18.3 c.c.
0.8% calcium formate	7.8 c.c.

Even using a condensing flask in which to carry the reaction, the amount of soda required varies by a fraction of a cubic centimeter when the tests are done in duplicate. The presence of calcium chloride lessens the amount of soda required up to a concentration of 0.34 %. Salt has no effect except when present in sufficient amount to raise the boiling point of the liquid. Calcium formate is as effective as calcium chloride, and its use has the advantage that both the salts produced are formates (calcium and sodium).

The following experiments indicate the effect of the presence of Magnesium, Barium and Strontium salts. In each case 5 c.c. of 40 % formaldehyde was used in 250 c.c. of water, and the sodium hydrate dripped slowly into the liquid boiling in a condensing flask.

25 c.c of 2% Solution.	Amount of 3.5% NaHO to complete reaction.
Magnesium sulphate	20.5 c.c.
Barium chloride	14.1 c.c.
Water only	22.0 c.c.
Strontium chloride	15·7 c.c.
Water only	21.9 c.c.

The reaction lags considerably, and if the addition of sodium hydrate is made rapidly, a white precipitate is apt to form, particularly in the case of the magnesium, which only redissolves slowly, in the form of a soluble formate.

Hence the presence of a magnesium salt exercises little or no katalytic action on the polymerization of formaldehyde to sugar by caustic soda, and Barium and Strontium salts are less effective than calcium salts.

The influence of temperature.

Not only is dilution a condition for the abundant polymerization of formaldehyde to sugar by alkalies, but also a high temperature. Thus using Barium hydrate and 1 % per cent. formaldehyde the times required to complete the reaction on a water bath at 80° C., boiling at 100° C., and in an autoclave at 110° C., were respectively 5, 3 and 1.

In addition, however, at low temperatures less and less sugar is produced, and finally only formates. Thus Barium hydrate kept in contact with 10 %, 4 % and 2 % formaldehyde for 3 months at 10-12° C., in sealed receptacles, was partly converted into Barium formate and some methyl alcohol and barium carbonate appeared, but no reducing sugar.

Similarly 250 c.c. water and 25 c.c. of 3.5 % NaHO and 5 c.c. of 40 % CH_2O after 3 months at 10° C. to 12° C., yielded sodium formate, but no reducing sugar, and a trace of CH_2O remained unaltered.

The same applies when sodium hydrate is used in conjunction with calcium chloride. Thus 500 c.c. of water, 10 c.c. of 40 % CH_2O, 10 c.c. of 17 % $CaCl_2$, and 15.5 c.c. of 3.5 % sodium hydrate after 3 months at 12° C., the liquid still contained CH_2O, but was practically neutral to litmus and feebly alkaline to phenolphthalein (as in the case of dilute sodium formate), is contained no reducing sugar and calcium and sodium chlorides and formates, mainly as calcium chloride and sodium formate. In some similar tests, using double the quantity of formaldehyde, a trace of reducing sugar appeared, but only a mere trace, and the products otherwise were the same.

Tests for fermentable synthesized sugars.—Large samples of crude sugar were obtained from formaldehyde by the use of calcium formate and caustic soda. The concentrated and filtered syrup was diluted and fermented for three days at 30° C. with dry yeast and with frest yeast after the addition of Pasteur's ash. The fresh yeast showed signs of budding and increased in amount. A fair quantity of carbon dioxide was formed. The distillate gave the iodoform test for alcohol readily and contained between 3 and 4 % of alcohol. The residual liquid after distillation contained a large amount of reducing sugar. It was optically inactive, and formed a good culture medium for various Bacilli and for *Penicillium* and *Eurotium*, particularly with the addition of Pasteur's ash.

Cultures supported fresh crops of fungi for weeks, but remained optically inactive throughout.

Chemosynthesis of sugar from CO_2 and water.—It is well known that powdered magnesium will cause traces of formaldehyde to appear slowly in a solution of carbon dioxide in water. 250 c.c. of water with 2 grains of Magnesium were charged with carbon dioxide under pressure for 3 weeks at 12 to 15° C., and then boiled in a condensing flask for 2 days. After then boiling to a small bulk and filtering, the filtrate was evaporated nearly to dryness and excess of hot absolute alcohol added. The filtrate on evaporating to dryness left a gummy residue readily soluble in water, optically inactive and containing reducing hexose and pentose sugar, one of the former being apparently a levulose and giving the ketohexose test with resorcin, while the pentose gives the usual precipitate with phloroglucin and HCl soluble in amyl alcohol.

Summary.

The polymerization of formaldehyde to sugar by alkalies and alkaline carbonates has been investigated.

The main conditions for a high proportion of sugar are appropriate dilution and a temperature of 100° C. to 110° C. The by-products are formates and methyl alcohol mainly. At low temperatures little or no sugar is produced.

The most rapid reaction is produced by sodium hydrate. In the presence of a neutral calcium salt, the amount of sugar condensation is greatly increased, less alkali is required and less formate produced. Neutral Barium and Strontium salts are less effective as condensing katalytic agents.

The best method is by running 7 to 8 c.c. of 3.5 % sodium hydrate into 250 c.c. of 0.8 % calcium formate containing 5 c.c. of 40 % formaldehyde while boiling in a condensing flask. The reaction is completed in a few minutes, and as soon as a pale yellowish tinge appears, all the formaldehyde has disappeared.

The sugar mixture is optically inactive, and contains reducing pentoses and reducing fermentable hexoses. Carbon dioxide and water are readily polmerized to sugar by the aid of magnesium. The production of calcium tartrate during sugar synthesis has not been confirmed, and was possibly due to the use of an oxidized sample of formaldehyde.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919].

Art. XVII.—*New or Little-known Victorian Fossils in the National Museum.*

Part XXIII.—On some Hydroid Remains of Lower Palaeozoic Age from Monegetta, near Lancefield.

By FREDERICK CHAPMAN, A.L.S., &c.
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(With Plates XIX. and XX.).

[Read 12th December, 1918].

Introductory Note.

So far as I am aware no fossils which can be referred to the Hydroid Coelenterates of the Order *Calyptoblastea*, other than the *Dendrograptidae*, have yet been recorded, with some possible exceptions in the Pleistocene. It is rather puzzling to note this fact, seeing how abundant the "Sea-firs" (*Sertulariidae*), the Plumularias and the Campanularias are at the present day. And this is especially so when we take into account the chitinous structure of the hydrosome.

Some forms, however, which have been figured by Ruedemann[1] under the generic names *Chaunagraptus* and *Mastigograptus*, closely approach the present specimens; in fact, one of our species seems referable to the latter genus.

On account of many points of resemblance with hydroids of the Campanularid type, the presently described fossils are referred with little hesitation to this group. Thus the Victorian specimens show an absence of bilateral or radial symmetry which is a distinctive character of the Graptolites, the hydrosome is more irregularly flexuose pointing to a rooted habit, and there is undoubted evidence of gonothecae attached to the hydrosome.

It is only right to mention here that Ruedemann himself, in discussing the general affinities of the graptolites with modern hydrozoa says, in regard to the conical thecae of some of these forms now under notice[2]:—"It can be said that this type of thecae would be more similar to the thecae of the hydrozoans" [sic-

1 Rep. N.Y. State Mus., Mem. No. 11, 1908. Ruedemann.—"The Graptolites of New York," pt. ii., pp. 210-228, pls. ix.-xii.

2 Op. cit., p. 213.

Sertularids and Campanularids] "than any other of the graptolites, first by the basal constrictions, second by the presence of the paired appendages. It has repeatedly been pointed out as an important difference between the graptolites and the hydrozoans that in the latter the point of communication between the hydrothecae and tube of the hydrocaulus is more or less constricted, and in the graptolites the theca is in uninterrupted continuous communication with the coenosarcal canal. . . . I learn from Dr. Ulrich that he also, on finding the material at once recognized its great similarity to the Sertularians and its possible phylogenetic importance."

One of our present types, here referred to, *Archaeocryptolaria skeatsi*, gen. et. sp. nov. might possibly be thought to show affinities with McCoy's *Protovirgularia*,[1] and especially to Ruedemann's tentative reference of some fossils[2] from the Normanskill Shale of Stockport, New York State. The only resemblance, however. between those forms and the Victorian fossil are the straight slender axis and the thecae disposed at right angles to it; but the morphological differences of those thecae are so great as to make a final and close comparison impossible. Thus the thecae in McCoy's oiginal specimens are of the pennatulid type and set serially on the lateral branches, whilst those in Ruedemann's fossils are simple hydrothecae, etc., with extraordinary inflated apices in many cases. These latter fossils are suggested by Ruedemann to have a possible affinity with *Thamnograptus typus*.[3]

For the interesting discovery of these remarkable and wonderfully preserved specimens we are indebted to Prof. E. W. Skeats, D.Sc. They were obtained between 1911 and 1917, and occur in a black slate or shale two miles E.N.E. of North Monegetta, south of Romsey. This slate also contains a brachiopod which I am able to refer to *Acrotreta antipodum*, Chapm., the rock being with little doubt of a similar age to the Lancefieldian of the Mount William and Lancefield districts, from which horizon I have lately described the above-named fossil.[4]

To Mr. Wm. M. Bale, F.R.M.S., I would express my best thanks for his valued opinion on the generic affinities of these interesting fossils and the corroboration of my own conclusions.

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1 *Protovirgularia dichotoma*, McCoy. Ann. and Mag. Nat. Hist., ser. 2, vol. vi., 1850, pp. 272, 273. Id., Brit. Pal. Fossils, 1852, p. 10, pl. iB., figs. 11, 12.

2 ? *Protovirgularia dichotoma*, McCoy. Ruedemann.—"Graptolites of New York," loc. cit., pt. ii., p. 243, pl. x., fig. 9; pl. xi., figs. 8, 9.

3 Loc. cit., p. 244.

4 Proc. Roy. Soc. Victoria, vol. xxx. (n.s.), pt. ii., 1918, pp. 145-148, pl. xxvi.

Description of Fossils.

[The following diagnoses of the specific forms are based on the material to hand, though these may require some further emendation as to specific boundaries and relationships.]

Order CALYPTOBLASTEA. Fam. LAFOËIDAE.

Genus **Archaeolafoëa**, gen. nov.

Generic Characters.—Hydrocaulus slender, flexuous and with few lateral branches. Length about 40 mm. Hydrothecae long-conical, narrowing slightly towards the base; aperture circular; borne equally along the sides of the axis and the branches, and set at angles of 15° to 50°. Periderm transversely wrinkled. Gonotheca small, elongately pyriform.

This generic type resembles the living genus *Lafoëa*, Lamouroux,[1] which is a common form in European and North American waters, and also occurring in the West Indies and the Straits of Magellan. The living specimens of the genus have not yet provided any examples with gonosomes.

Archaeolafoëa longicornis, gen. et sp. nov. (Plate XIX., Fig. 1. 1*a*; Plate XX., Fig. 5).

Description.—Axis of hydrocaulus slender, flexuous. Occasionally with secondary branches. Hydrothecae long, gradually tapering near base and often geniculate. Aperture circular and slightly everted. Periderm of thecae marked with fine transverse wrinkles. Axis scaly. Gonothecae, long-pyriform, shorter than hydrothecae.

Length of hydrosome about 40 mm. Width of axis, .5 mm. Length of hydrothecae about 5 mm. Length of gonothecae about 2 mm.

Observations.—As regards the general form and disposition of the hydrothecae the above species reminds one of *Lafoëa fruticosa*, Sars.[2] The axis in the fossil form is, however, flexible and twisted and does not show the vertical ridging and grooves of the living

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1 Expos. Méthod., 1821.

2 Bemaerk, over fire norske Hydroider, Vidensk. Forhandl., 1862. Hincks, Brit. Hydroid Zooph., p. 202, pl. xli., fig. 2. Allman, Rep. Chall. Zool., vol. xxiii., pt. lxx., 1888, p. 34, pl. xvi., fig. 2, 2*a*.

form. *Lafoëa dumosa*, Fleming sp.[1] compares rather closely with the fossil in its more flexible axis and long-conical hydrothecae.

Genus **Mastigograptus**, Ruedemann.[2]

Note.—The reference to the genus Mastigograptus, of the Victorian species given below, is made in a restricted sense, taking M. tenuiramosus, Walcott sp. as the type.[3]

Mastigograptus is a genus which has occurred in the Utica Slate of Trenton, New York, the equivalent of the Llandeilo Series (Middle Ordovician) of Great Britain. The description of Mastigograptus tenuiramosus, Walcott sp. as given by Ruedemann is as follows[4]:—

"Rhabdosome forming a densely branched bush attaining a size of 20 cm., the branches extremely slender, especially in their long distal portions (.3 mm. average width), given off monopodially and alternatingly small, somewhat irregular intervals (1.5 mm. at an average) and at an angle of 50°; this rather large angle giving the bushes a characteristic shrubby appearance in the central parts [see pl. IX., fig. 2], while the distal parts are inclined to become pendent. The branches are filiform, smooth, as a rule retaining but a central row of circular pits (about 2.2 mm. apart from each other), apparently only on one side of the branch. When perfectly preserved, rows of long conical pedunculate, obliquely ascending appendages, 1.2-1.5 mm. long are observed bearing on their pedunculate bases pairs of similarly shaped, usually shorter and slightly inward curved opposite cones."

Mastigograptus monegettae, sp. nov. (Plate XIX., Figs. 2, 2*a*: Plate XX., Fig. 6).

Description.—Axis moderately straight, occasionally branching. Hydrothecae long, slender and conical; attached to axis by a slender peduncle. Gonothecae not so long as the hydrothecae, long-pyriform and broad near the aperture.

Length of the axis, 23 mm.; thickness, .75 mm. Length of hydrothecae, 8 mm. Length of gonothecae, circ. 4 mm.

Observations.—In the Victorian species the hydrothecae are apparently attached to the axis without the slender pedunculated

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1 *Sertularia dumosa*, Fleming, Edin. Phil. Journ., vol. ii., p. 83. *Lafoëa dumosa*, Fleming sp., Hincks, loc. supra cit., p. 200, pl. xli., fig. 1. Allman, loc. supra cit., 1888, p. 34, pl. xv., figs. 1, 1*a*.

2 Rep. N.Y. State Mus., Mem. No. 11, 1908, p. 210.

3 See Ruedemann, op. cit., p. 216.

4 Loc. cit., p. 216.

base, as in *M. tenuiramosus;* otherwise the shape of the cups are similar. The axis in *M. monegettae* shows less tendency to branch than in *M. tenuiramosus*, but it is difficult to be emphatic on this point on account of the incompleteness of the specimen.

Genus **Archaeocryptolaria**, gen. nov.

Generic Characters.—Hydrocaulus slender, more or less erect or slightly flexuous, length up to about 30 mm. Hydrothecae cylindrical or long-conical, narrowing very slightly towards the base; adnate and attached for some distance along the axis; aperture circular and lip slightly everted. Periderm coarsely wrinkled or scaly. Gonothecae elongately pyriform and incurved to the axis.

This generic type resembles the living genus *Cryptolaria*, Busk,[1] which is practically confined to the Pacific and Southern Oceans.

Archaeocryptolaria skeatsi, sp. nov. (Plate XIX., Fig. 3; Plate XX., Fig. 7).

Description.—Axis flexuous, but not so much as in the preceding species; with a tendency to sigmoidal curvature. Hydrothecae shorter than in *Archaeolafoëa longicornis*, and not so tapering at the junction with the stem, where they are decurrent for some distance and suddenly bent outwards, almost at right angles in the majority of cases. No gonothecae noticed in this form up to the present.

Length of hydrosome about 25 mm. Width of axis, .5 mm. Length of hydrothecae about 2.5 mm.

Observations.—The long cylindrical form of the hydrothecae in this species, together with the geniculate bend after leaving the axis is like that seen in *Cryptolaria angulata*, Bale,[2] a living species found at 100 fathoms in the Great Australian Bight. *Cryptolaria flabellum*, Allman,[3] also shows a strongly flexed hydrotheca, which, however, is curved rather than sharply bent. The periderm in the fossil shows the transverse rings as seen in the living forms.

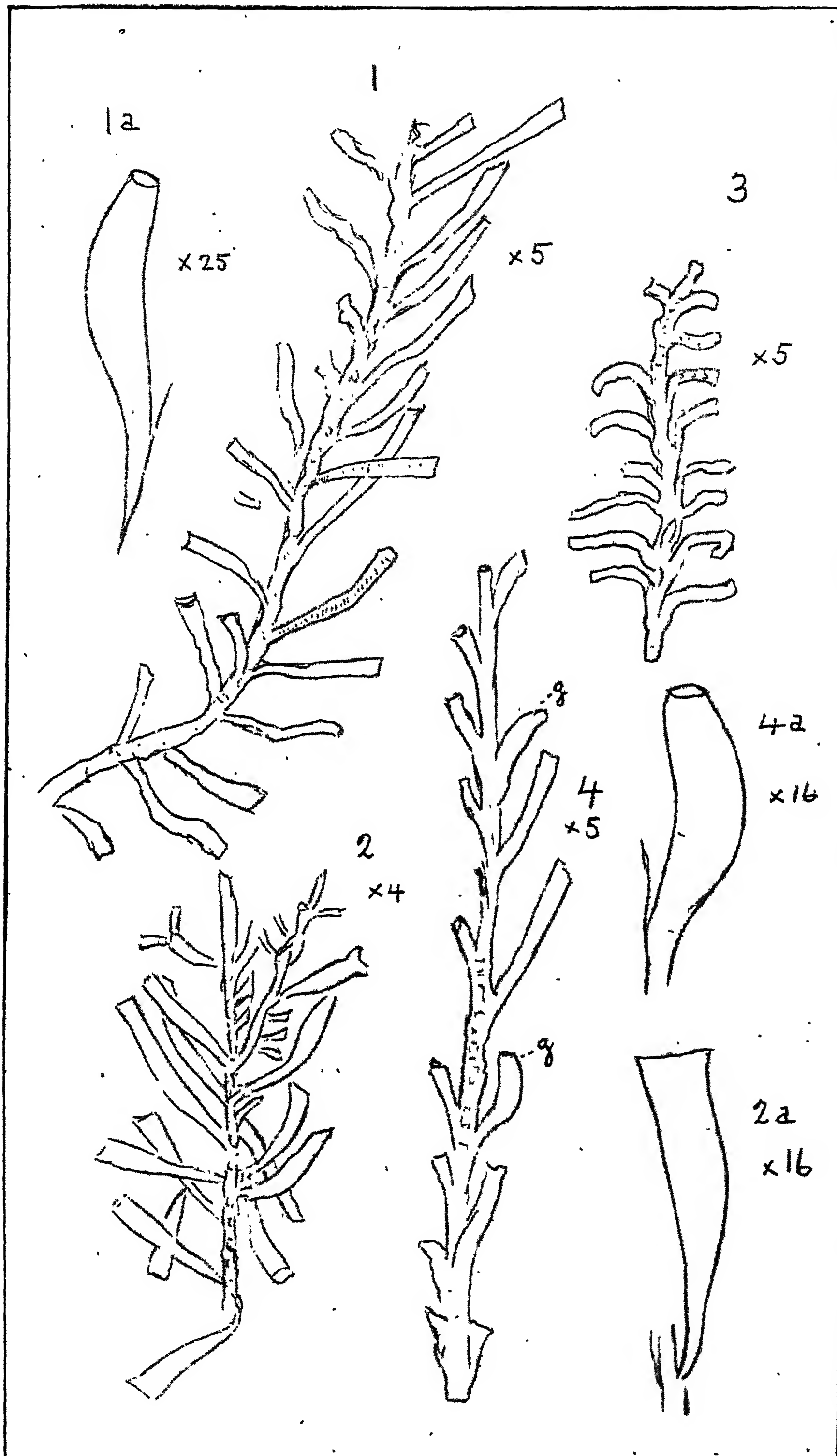
Archaeocryptolaria recta, sp. nov. (Plate XIX., Figs. 4, 4*a*; Plate XX., Fig. 8).

Description.—Axis straight, comparatively stout. No branches in described examples. Hydrothecae long, tapering to base,

1 Quart. Journ. Micr. Sci., ser. i., vol. v., 1857, p. 173. Rep. Chall. Zool., vol. xxiii., 1888. Allman, p. 37. See also this paper, pl. xx., fig. 9.

2 Biol. Results, "Endeavour," vol. ii., pt. iv., 1914, p. 166, pl. xxxv., fig. 1.

3 Rep. Chall. Zool. vol. xxiii., pt. lxx, 1888: Hydroida, pt. ii. p. 40, pl. xix., figs. 1, 1*a*.



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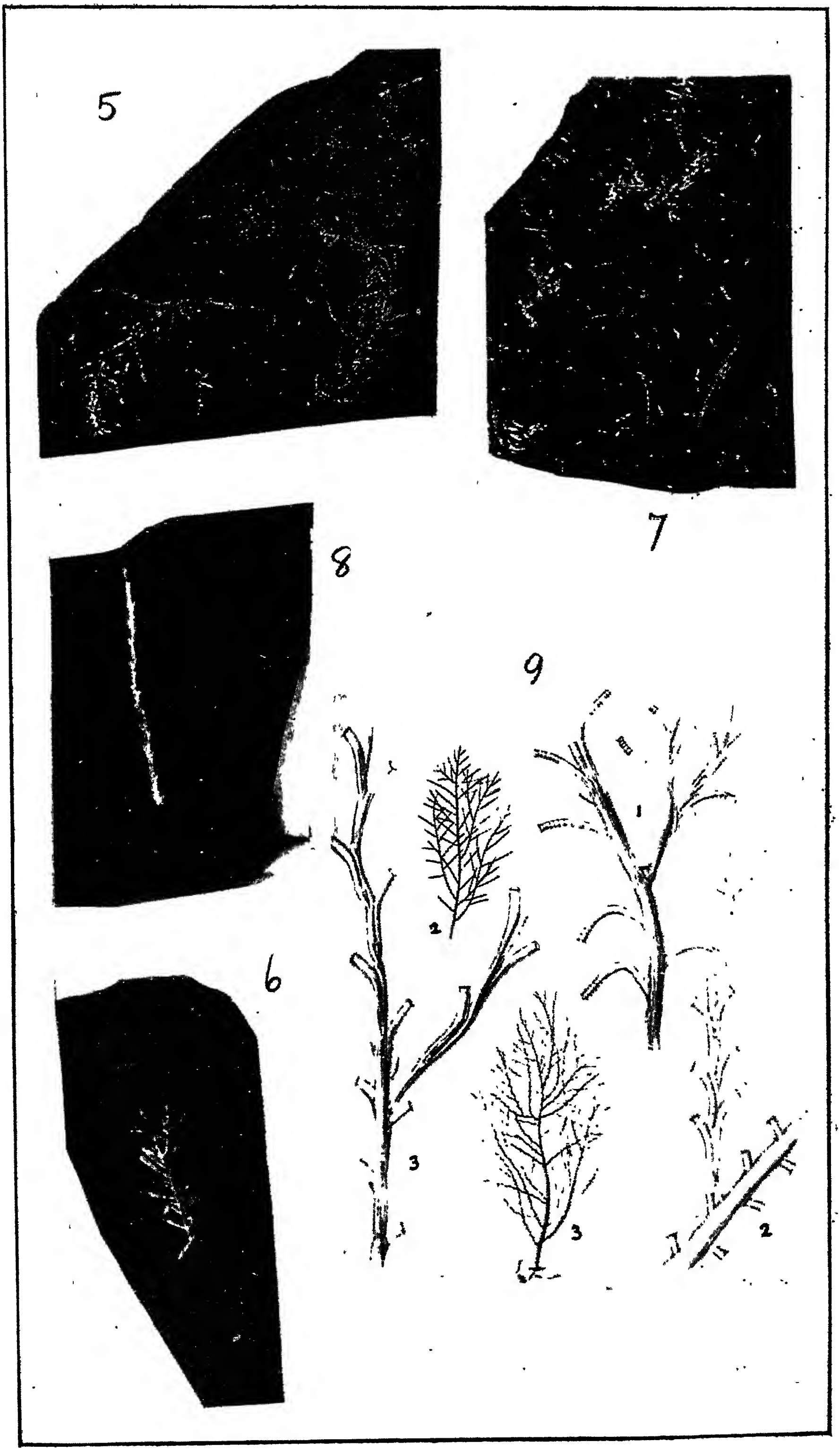
Palaeozoic Hydroids: Monegetta, Victoria,



F.C. Photo

Palaeozoic and Living Hydroids. Monegetta, Etc.

adnate, slightly curved and directed upwards towards the axis, making an angle of 18°. Gonothecae short, pyriform, situated between the hydrothecae at irregular intervals; walls constricted just below the circular orifice, as in *Cryptolaria abyssicola*, Allman.[1] These are best seen on the counterpart slab.[2]

Length of axis, 32 mm. Approximate width of axis, .9 mm. Length of hydrothecae, 4 mm. Length of gonothecae, 1.75 mm.

Observations.—The general habit of this species shows a parallelism with a branch of *Cryptolaria abyssicola*, Allman, a species previously mentioned, found living south of South Australia and west of Tasmania, in 2600 fathoms. The points of similarity are the straight or erect form of the axis, the regular disposition of the hydrothecae, and the form of the gonothecae.

EXPLANATION OF PLATES.

Plate XIX.

Fig. 1.—*Archaeolafoëa longicornis*, gen. et sp. nov. × 5. 1*a*, gonotheca × 25. Lower Ordovician. Monegetta.

Fig. 2.—*Mastigograptus monegettae*, sp. nov. × 4. 2*a*, gonotheca, × 16. Lower Ordovician. Monegetta.

Fig. 3.—*Archaeocryptolaria skeatsi*, gen. et sp. nov. × 5. Lower Ordovician. Monegetta.

Fig. 4.—*Archaeocryptolaria recta*, gen. et sp. nov. × 5. 4*a*, gonotheca × 16. Lower Ordovician. Monegetta.

Plate XX.

Fig. 5.—*Archaeolafoëa longicornis*, gen. et sp. nov. Lower Ordovician. Monegetta.

Fig. 6.—*Mastigograptus monegettae*, sp. nov. Lower Ordovician. Monegettae.

Fig. 7.—*Archaeocryptolaria, skea'si*, gen. et sp. nov. Lower Ordovician, Monegetta,

Fig. 8.—*Archaeocryptolaria recta*, gen. et sp. nov. Lower Ordovician. Monegetta.

(All the above photographs (figs. 5-8) are slightly larger than natural size.)

Fig. 9.—Reduced from Rep. Chall. Zool., vol. XXIII., 1888, Report on the Hydroida, Pt. II., by Allman, pl. XIX., showing three species of *Cryptolaria* (1. *C. flabellum*. 2. *C. pulchella*. 3. *C. crassicaulis*).

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1 Allman, loc. cit., p. 40, pl. xviii., fig. 2*a*.

2 In coll. of Geol. Dept. Melbourne University.

[PROC. ROY. SOC. VICTORIA, 31 (N.S.), PART II., 1919].

ART. XVIII.—*On the Growth, Treatment and Structure of some common Hardwoods.*

BY R. T. PATTON, B.Sc.

(Government Research Scholar).

(With Plate XXI. and Seven Text Figures).

[Read 12th December, 1918].

One of the great surprises of the war has been the enormous consumption of timber, but before the war the need of timber was great, and steps were taken in many countries to have supplies for future use. At the present time many believe we are faced with a timber famine in the near future, unless steps are taken to avert it. But before we can do anything in the way of providing for the future, and before we can make a definite working plan, we must know what our forests are capable of yielding under efficient management.

In Australia we have no managed forests which we can study, and we have no forests of known age, and therefore in constructing any yield tables we have to devise some method by which we can arrive at approximate rates of growth, and from these construct yield tables.

Since the publication of my paper last year, on the rate of diameter growth of Mountain Ash (E. regnans), a paper has been published by the New South Wales Forestry Department on the rate of growth of four species of Eucalyptus.

The method adopted by the N.S.W. Department is based on Sir William Schlich's method. An average tree is selected, and the bole is cut into a number of equal lengths, and the number of rings counted at the end of each length. From these results graphs are constructed. Schlich's method is open to very serious objections. In the first place it is almost impossible to select an average tree for the purpose. In working on these trees one finds the greatest variation between two trees which externally look similar. Again every variation of the single individual is taken as typical of the forest as a whole, otherwise the study of a single individual is meaningless. The objection to this method is shown in Fig. 6 of Bulletin No. 13, N.S.W. Forestry Commission. A forest changes gradually, and hence any graph representing it must not show any irregularities. Another difficulty experienced is that of counting the rings after about 90 years.

In dealing with the forest, by taking the average of as many typical trees as possible, we naturally eliminate individual variations very largely. Nature varies widely, but it varies around a mean, and it is the mean I have attempted to get.

Since the publication of my paper on diameter growth, a further series of measurements have been taken, and the resulting curve is very little different from the former one. I have attempted to carry the measurements to 100 years, but the results have not been satisfactory. The distinction between autumn and spring wood is not at all clear. With our long growing season and favourable weather it is not surprising that the limits of the rings are ill defined.

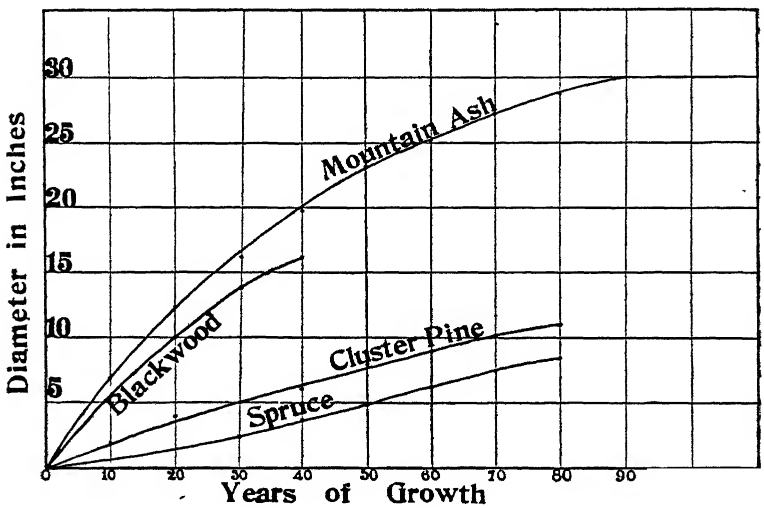

Fig. 1.

The figures on which the curve for Mountain Ash (Eucalyptus regnans) is based were obtained in the Warburton area, while those for Blackwood (Acacia melanoxylon) were obtained at Beech Forest. Mountain Ash appears to grow slightly slower in Beech Forest, but the studies were not completed. The other curves are inserted for comparison. The figures for these curves were obtained as follow: —Cluster Pine, State Forest, Leiria, Portugal, quoted in a paper at British Association, 1914, by E. D. Hutchins, and published in "Australian Forestry." Spruce, from "Farm Woodlot," by Cheney.

On comparing the graphs it will be noted that the curves for Mountain Ash and Blackwood differ widely from the others.

It will be noted that the curves for local trees indicate a very rapid growth from the commencement. Professor Masson has kindly pointed out that the curve for Mountain Ash is a mass action curve, and that this particular curve gives a remarkable set of constants. The question of growth curves cannot be discussed here, but suffice it to say that the Eucalypt appears to be anomalous. In general it may be said that the growth curve contains a point of inflexion—the gradient is at first increasing and subsequently decreasing. It is interesting to notice that Blackwood, an associate of Mountain Ash, has the same type of graph. Pinus insignis has a similar graph. Blackwood has been reputed a slow growing tree, but there is no evidence of this. It will be seen that good cabinet timber could be grown in 40 years. This rapid increase of diameter materially affects the management of the forest. It has been frequently stated in the press that we can regrow our forests in 40 years, but a detailed study of the forest fails to reveal any evidence of this. It is said that Mountain Ash will grow a butt of from 30 inches in 40 years. Individuals may do this, but we are concerned with the average over a wide area.

If we apply Schneider's formula $p=400/d.n$, where p=rate per cent. at which wood is being produced, d=diameter and n=number of rings in the last inch, we find that in Mountain Ash at the 80th year, $p=1.9$ %. Under skilful management it is more than probable that this rate could be considerably increased. The fuller the crown kept on the tree, the more timber formed. A study of the big timber shows that the rate of increase is below 1 %, and it is more than likely that in the virgin forest increase is compensated by decay. The fixation of a diameter limit for felling without reference to rate of growth has no justification.

Height.—The heights were taken either with an Abney level and tape, or measured along the ground as the trees were felled. While it was a simple matter to get a curve for diameter growth, it was not an easy matter to get a curve for height. If we had patches of trees of known age the matter would have been simple. The objection to the Schlich method for obtaining a height curve has already been pointed out. The method adopted here was to establish a relation between diameter and height and, to plot these results, diameter against height. This was done for a large number of trees growing in close canopied high forest, but only normal trees were measured.

Since we have already a relation between diameter and age, we can now establish a relation between height and age from the graph of height and diameter, and plot the new curve. This method enables one to study the forest where, as yet, no felling is going on, and it embraces all trees from the youngest to the oldest. The method has no value when once age classes, growing in close canopied forest, are available, but these will not be available until perhaps a century or more has passed, and in the meantime we want some basis for our working plans. It may be objected that the method would break down owing to the variability in the height of the trees. However, under a given set of conditions the variations revolve round a mean, and in the case of Mountain Ash the given set of conditions are rather rigid. If we vary one of these conditions, Mountain Ash ceases to grow, and another eucalypt takes its place. Messmate (E. obliqua), grows under widely differing sets of conditions, but each set of conditions has its own height growth curve. The method adopted in this paper is applicable to any species growing under the same set of conditions in any one locality.

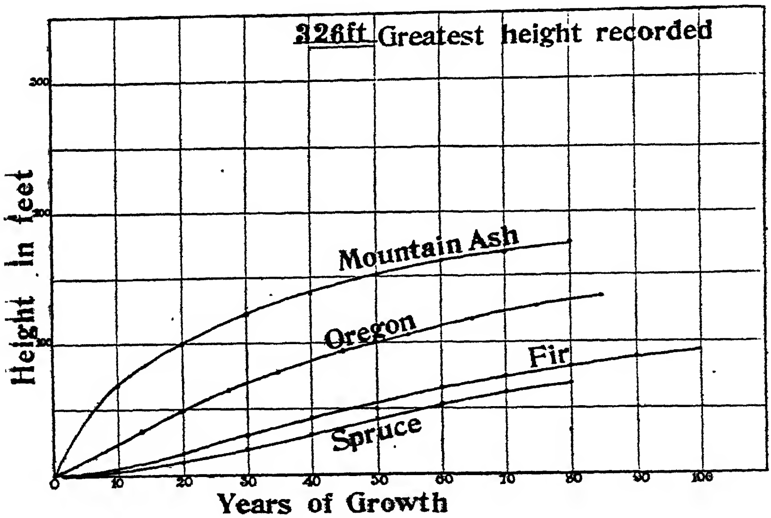

Fig. 11.

The figures for height growth were obtained mainly at Powelltown, but measurements were also taken at Belgrave, Warburton and the Ada Creek. Observations have also been made at Upper Yarra, Cumberland Creek, and Beech Forest. In the latter forest,

height generally appears lower than in the forests to the east of Melbourne. No satisfactory growth was available for Blackwood studies. The figures for the other curves, which are inserted for comparison, were obtained as follow:—Oregon from Maw's "Practice of Forestry," Fir from Fernow's "Economics of Forestry." The curve for Cluster Pine is slightly above that for Fir. It will be noticed that the curve for Mountain Ash is again a mass action curve. The eucalypt is here again somewhat anomalous, but the extraordinay rapid growth of many eucalypts during their early life has been pointed out in many parts of the world where they have been planted. Most plants grow very slowly during their early periods. The rapid growth in height partly explains why the eucalypt has no competitor in our forests. In "Australian Forestry," by E. D. Hutchins, it is recommended to underplant our Eucalypts with pines, but as these are light demanding, and as they are in general slower in growth than the Eucalypt, it is possible that the pines would be suppressed.

A good deal has been written about the height of our Eucalypts, and some very high figures have been given, but never proved. The two tallest I have seen were 261 and 249 feet. The official record is 326 feet. Whether or not we have the tallest trees is of little consequence. What does matter is which tree will reach merchantable size in minimum time, and in this respect Mountain Ash probably holds the record.

Taper.—The trunks of Mountain Ash are almost cylinders. The nearer the trunk approaches a cylinder the less waste in the conversion of the log. I have taken lengths up to 120 feet and have averaged the results. For every foot of ascent the taper is .36 inches of circumference.

Density of Trees per Acre.—In the managed forests of Europe the number of trees, on any area, at each decade is well known. Forestry has been practised under different systems for centuries, and the results are known and set out in tables. Graphs have been used only slightly. We have no such tables, nor have we any young forests which would give us this information. In those forests which we have, density of stocking has never been attended to. The aim of the forester must be maximum wood production per tree, combined with maximum number of trees per acre. The more trees per acre the smaller the crown, and hence the smaller the amount of wood formed. The converse is also true, within limits, but a large head is antagonistic to long clean boles. In order to construct a yield table this question of density per acre

has to be settled. A study of the mature or over mature forest was first made in order to determine the number of mature trees per acre. The largest number of trees found per acre was forty-one, and the next best area averaged 39.5 trees per acre.

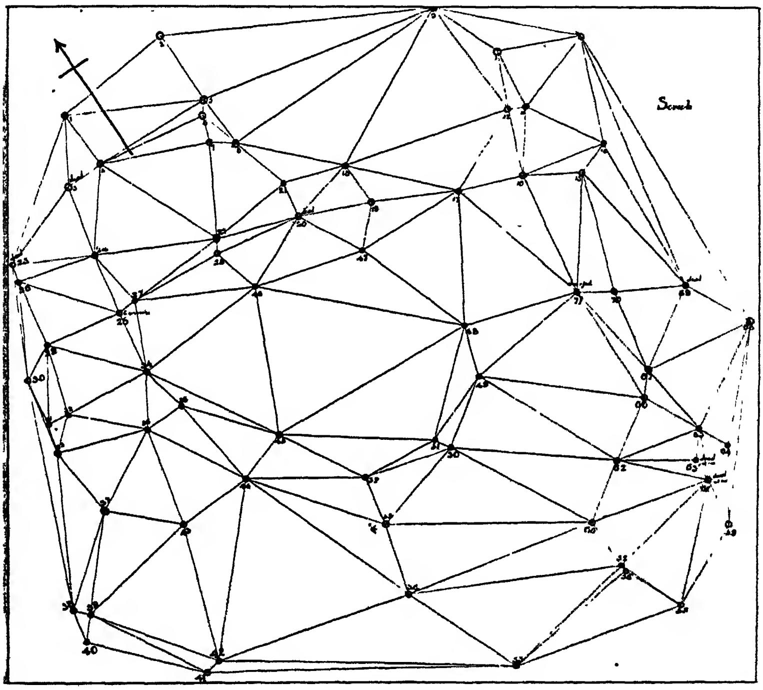

Fig. III.

Fig. III. is a survey of 1.7 acres at the Ada Creek, a tributary of the Latrobe River.

From the plan it will be seen that the trees are very unequally spaced, and that there are gaps in the forest. The crown canopy is not complete, and all the sun's energy is not being used for tree growth. From a long study of the crowns I came to the conclusion that a final spacing of 32 feet was suitable for these trees. This is not very great when we consider the height to which these trees grow. It may be objected that many trees, in fact numbers, do not form so big a crown. This is so; but these big trees with so small a crown are not thrifty trees, as they have not the leaf area to make a large amount of wood. These small crowns are due to the severe struggle for existence, but in a controlled forest the struggle would be relieved by thinning, and hence the trees would carry well formed crowns.

Spacing at 32 feet, and assuming the trees are so distributed that the crowns are hexagonal, there would be 49.13 trees per acre, or say 50.

Planting trees on the square does not fully utilise the ground. If we now work back we can ascertain how many trees there are in each crown class. The crown class preceding the 32 ft. class must be the 16 ft. class since trees are fixed in the one spot. If there are 50 trees per acre in the 32 ft. crown class, there must be 200 trees per acre in the 16 ft. class, that is by halving the diameter we increase the number of trees four times. The crown classes must be 32 ft., 16 ft., 8 ft., 4 ft., 2 ft., and 1 ft. When any one crown class passes into the next higher class, 3 out of every 4 trees are suppressed, and this is why thinning is necessary. The number of trees in any crown class may be found by the following expression.

$$q = ar^{n-1}$$

Where q = the required number of trees.

a = number of trees in the final crown class.

$r = 4$.

n = number of crown classes to and including class required.

From this we find that in the 1 ft. crown class there would be 51,200 trees.

It is customary to set out tables showing the number of trees at each decade. These tables are the result of experience. Nature does not work from decade to decade, but from crown class to crown class, and suppression is her mode of working. If we can conceive of a forest advancing from class to class, then we have a scientific basis for thinning. We have, however, to find some relation between the crown classes and the time taken to reach those crown classes. It has already been noticed that Mountain Ash starts with maximum effort in both diameter and height growth, and it might be supposed that the growth of the crown would be similar. However, the crown is not free to expand, but must struggle for its expansion, hence its curve of growth must differ from those of diameter and height. A study of the crowns suggested that the expansion of the crowns could be expressed as follows:—

$$t = ar^{n-1}$$

Where t = required age of a particular crown class.

a = known age of a particular class.

r = ratio.

n = number of crown classes concerned.

The study suggested that the value of r lay between 2 and 2.5. If the value be 2 then the expansion of the crown is a linear function of time. This is interesting when we remember the curves for both height and diameter. If the value of r be 2, then it takes double the time to double the crown, and when the crown reaches 32 feet in diameter there is an abrupt termination of lateral growth. This deduction is an objection to the suggested manner of expansion of the crown. Yet we are familiar with the apparent constancy of the size of the crown of mature trees. A detailed study of the sapling forests does not reveal any rapid expansion of the crown comparable to the growth in height and diameter. The relation between crown class and age seems to be that at about 8 years the 4 ft. crown class has reached maximum congestion and suppression occurs, and about 16 years the 8 ft. crown class is congested. From these figures we find that the 32 ft. crown class would be reached in 64 years. This seems somewhat

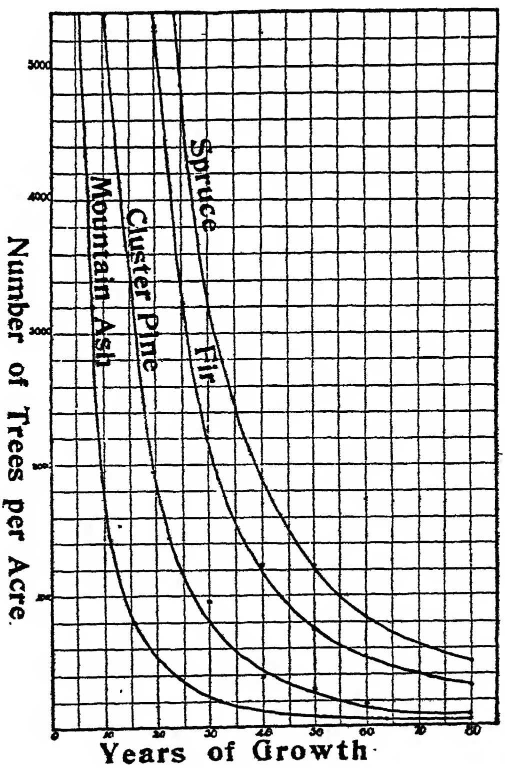

Fig. IV.

early, and therefore suggests that the value of r lies between 2 and 2.5, but it is certainly not greater than 2.5. It may be that the expansion of the crown is a linear function of time, but towards the end of the expansion the growth is slower, and hence the graph is no longer a straight line. It may be, however, that the graph is not linear, but during the earlier stages of crown expansion it approximates to a straight line. It is probably true that the value for r is the same for all close canopied pure forests. The difference between forests is due to the time taken to pass from one crown class to another. In other words, the forests differ in the intensity of the struggle for existence, and this intensity reaches a maximum, probably, in Mountain Ash forests. Since we know the number of trees in each crown class, and the age of each crown class we can plot the result.

The curve for Mountain Ash is a theoretical curve, the curves of Fir, Spruce and Cluster Pine are taken from tables, the sources of which have already been indicated. Very few tables were available for comparison, as our forestry literature is extremely limited. These curves, while giving the number of trees per acre at any particular year, are in reality the curves of the struggle for existence. It will be seen that the number of trees at any future period is equal to the present number of trees divided by the square of the quotient of the future age and present age. Expressing as an equation—

$$x = \frac{n}{\left(\frac{y}{z}\right)^2}$$

Where x = future number of trees.
n = present number of trees.
y = future age.
z = present age.

This seems to be the equation for the struggle for existence for any species competing for the same necessaries of life. The equation is only true until maturity is reached; after that the mortality is due to other causes.

From this view of the forest several suggestions stand out.

Each given set of conditions determines the ultimate size of any given species when grown in close canopy. Hence if the ultimate size of the mature tree varies with the environment, then the spacing of the trees when being planted out must be varied according to the site. No arbitrary distances, for all classes of soils, can

be fixed. Yet this is what we are doing, and failing in a large number of cases.

From a former equation it will be found that the number of trees in the 1 ft. crown class would be 51,200. This figure has been regarded as altogether out of reason, but in a book just to hand, "Seeding and Planting in the Practice of Forestry," by J. W. Toumey, Professor of Silviculture at Yale, it is stated that the best results for oak and beech abroad are attained in direct seeding, which gives 50,000 seedlings or more per acre. Professor Toumey says: "We have failed to appreciate the necessity in most species for the germination of a large number of seeds per acre." For Mountain Ash probably 10,000 to 12,000 seedlings per acre may be regarded as satisfactory, but we are not getting this at present. We might even go as low as 4000, but the result would be very doubtful. The whole practice of forestry must be based on the survival of the fittest. The dangers of too open a forest cannot be too strongly emphasized, but this is not our subject. If we regard the forest as developing in crown classes, we have a basis for the practice of thinning. This forest practice is still debated, but when we remember that three out of every four trees are killed in every advance to the next crown class, thinning must be practised. Thinning merely anticipates nature and removes the trees which are being suppressed before they have injured the crown or form of the surviving trees. A full and well formed crown must be the constant aim of the forester.

Seasoning of Timber.—Since these experiments were commenced two new American books on the subject of kiln drying have reached here, and these deal fully with the subject. The type of kiln which has been adopted by U.S.A. Forest Service is undoubtedly efficient. The control of the humidity of the air in the kiln was obviously defective in our kilns here, and I worked upon the subject, but since these books have appeared there is no need to proceed further since the method adopted for controlling humidity is evidently successful. However, interesting points have arisen during the course of the year, which throw considerable doubt on the need for kiln drying on a large scale. With our dry summer climate, long hot days, and almost constant winds, we have a set of conditions at Melbourne most favourable for rapid drying. There is a belief that the place to season timber is where it is grown, but it remains for those who assert this to prove it.

Both in kiln drying and, in some cases in natural seasoning, the wood is first steamed in order "to open the pores," so that the

wood will subsequently dry faster. As a matter of fact there are no pores in the wood to open, and hence from this point of view the work of steaming is useless. The only pores in our hardwood timber are at the ends, and these are already open. To test the efficiency of the process, 4 ft. lengths of 4 in. x 2 in. Mountain Ash were cut into 2 fts., and each weighed. One half was left in the air and the other half placed in a steam bath at atmospheric pressure. Pieces were left in the steam bath for periods ranging from 6 hrs. to 72 hrs. In all cases the weight of the piece when taken out of the bath and cooled was just about the same as when it went in, and this is what was expected. The pieces were weighed regularly, but both pieces, the steamed and the unsteamed, lost moisture at the same rate. The idea of the steam opening the pores of the wood is pure fallacy. However, after three months the steamed pieces began to shrink more than the unsteamed, and this went on until there was a marked difference in size between the two halves of each original length of timber. Although the steamed pieces were shrinking more than the unsteamed, yet both pieces were losing moisture at the same rate. A typical example may be given :—Nos. 7 and 8 were cut out of the same length of timber. No. 7 was steamed for 24 hrs., and No. 8 was not treated.

Date.		Weights of No. 7.		Weights of No. 8.
16.5.18	...	6 lb. 14½ oz.	...	6 lb. 13½ oz.
17.5.18	...	6 lb. 15 oz.	...	6 lb. 11 oz.
19.5.18	...	6 lb. 9 oz.	...	6 lb. 8 oz.
1.6.18	...	5 lb. 15 oz.	...	5 lb. 14½ oz.
15.7.18	...	5 lb.	...	5 lb.
9.9.18	...	4 lb. 11 oz.	...	4 lb. 10 oz.
7.11.18	...	4 lb. 7 oz.	...	4 lb. 6½ oz.

The shrinking of the steamed specimens is probably due to the steam slightly breaking down the structure of the wood. So far there does not appear to be any justification at all for steaming timber.

Many merchants stand the timber on end when naturally seasoning. The argument is apparently that the sap runs down the length of the timber. When the trees are felled sap does run out from the cut ends of the wood vessels, but this sap was in the cavity of the vessel. The moisture which is lost in seasoning is held in the walls of the cells. Hence this cannot run down the stem. It can only be lost by diffusion. To test the question, however, several experiments were carried out,

but none of these justifies this end stacking. Lengths of 4 in. x 2 in. Mountain Ash were cut into sets of $1\frac{1}{2}$ in., 3 in., 6 in. 1 ft., 2 ft., 4 ft. Four of these sets were made. The sides of the timber were paraffined so as to prevent all lateral evaporation, but the ends were left open. Two sets were placed vertically and two sets were laid horizontally. The vertical sets ought to have dried the more quickly, but this was not so. All four sets dried at about the same rate, the reason being that the moisture is lost by diffusion. The following graph shows the rates at which each length was drying.

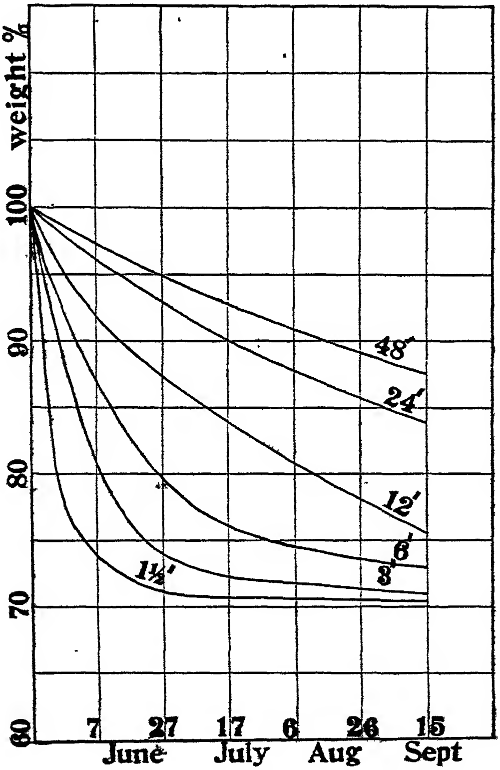

Fig. V.

Corresponding pieces which were not paraffined dried much more rapidly, showing that the loss of moisture is from the sides, not from the end of the timber. The theory of end drying was further tested by cutting a 10 ft. of E. goniocalyx into 2·5-fts., one being placed vertically and the other horizontally, the latter one resting

on blocks on a table so that there was a free supply of air on all sides. The following table shows the results. Weights are expressed as percentages of the original weight.

Date.		Weight of Upright Beam.		Weight of Horizontal Beam.
		%		%
21.6.18	...	100	...	100
1.7.18	...	93.0	...	92.0
12.8.18	...	82.2	...	81.3
9.9.18	...	77.8	...	77.0
8.10.18	...	75.3	...	73.9
7.11.18	...	71.6	...	70.8

It will be seen that the horizontal beam has slightly the advantage in the rate of drying. Timber loses its moisture by diffusion through the sides of the timber, and therefore it does not matter how the timber be stacked provided there is a free supply of air all round it. The question was further tested by suspending a beam of 4 in. x 3 in. from the ceiling of the laboratory and taking the moisture content of the top and bottom of the beam each month. The result is as follows:—

Date.		Moisture Upper End.		Moisture Lower End.
		%		%
27.6.18	...	47.2	...	46.4
10.7.18	...	45.3	...	45.9
12.8.18	...	35.6	...	36.0
27.9.18	...	27.3	...	28.6

It will be seen that in this instance the lower end did have a slight excess of moisture. The question has been worked on in other ways, but no evidence is in favour of vertical or oblique stacking. The reason why timber so stacked does dry more quickly than timber in the rack is because the former is exposed freely to the air, while in the rack the timber is stacked in a mass where there is no circulation of air. It has already been mentioned that timber in long lengths loses moisture mainly through the sides, and not so much from the ends; but it was not known what part each surface took in drying. To ascertain this cubes were used from 1 in. up to 4 in. They were made in sets of 5, each set being cut from the same piece of timber. In all cases timber was selected which had the rings parallel to one side. In each set, one cube had all faces left clean, one had all six faces paraffined, and

one had the radial faces left clean, one the tangential faces and one the cross section faces clean. In waxing them, the paraffin was heated to just above boiling point of water and then the face of the cube was brought into contact with the surface of the paraffin. When the paraffin set the process was repeated. This gave a very satisfactory result. In all the sets made the cubes which had the cross section faces left clean dried almost as quickly as the cube which had no paraffined faces. This is due to the vessels being small tubes running through the cube and therefore increasing the evaporating surface. This rapid drying from the ends does not extend far up the length, as will be shown later. It explains why logs left exposed to the sun split so badly at the ends.

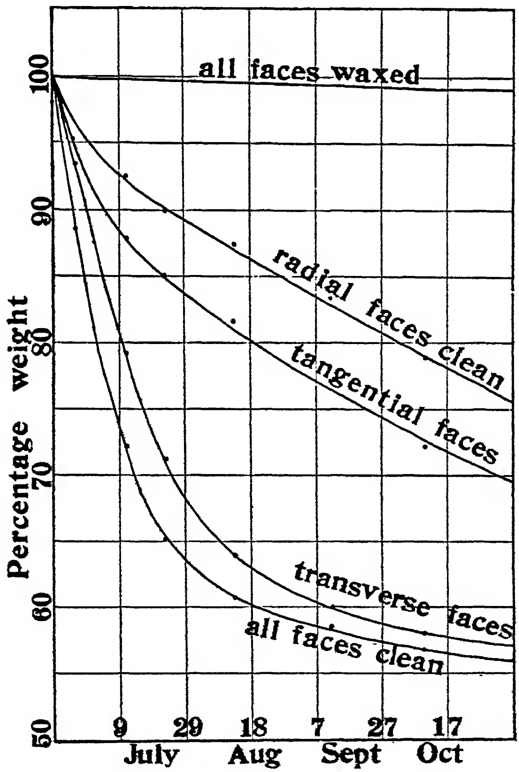

Fig. VI.

Fig. VI. gives a typical series of curves for the drying of the cubes by the various faces.

In all cases, except in the inch cubes, the tangential faces lost moisture more readily than the radial faces, but the difference from a commercial standpoint is negligible. The reason for the tangential faces losing moisture more rapidly is because of the large number of medullary rays, and these allow the moisture to escape. It is perhaps as well to explain that timber cut tangentially is said to be cut on the back, while if it is cut radially it is said to be cut on the quarter. As practically all the drying of a cube takes place from the transverse faces a comparison was made between a length of timber with all faces clean and a length which had the sides paraffined. Each piece was 4 ft. The loss of moisture from the paraffined piece has been very slow, and on a long length the influence of the ends would be negligible.

The percentage weights of the two pieces are as follow :—

Date.		Sides and Ends Clean.		Sides Waxed, Ends Clean.
		%		%
18.5.18	...	100	...	100
1.6.18	...	87.7	...	97.5
15.7.18	...	73.0	...	91.6
12.8.18	...	69.0	...	89.0
9.9.18	...	66.2	...	86.0
8.10.18	...	63.4	...	82.2
7.11.18	...	62.1	...	78.8

A test was made with both tangentially cut boards and radially cut boards to see if the loss of moisture was affected by lying the boards flat or standing them on edge. If drying be due to diffusion of moisture, then the manner of stacking ought to have no effect. It was ascertained later that some timber men in America prefer edge piling in the kiln to flat or ordinary piling. So far as can be ascertained, edge piling is not practised here. For the experiment the ends and two corresponding sides were paraffined. If the clean faces were placed vertically, then diffusion would be lateral, but if the clean faces were placed horizontally, then diffusion would be up or down. No difference in the rate of drying was observed either for the radially or tangentially cut faces. There may be, however, mechanical advantages in edge piling in a stack of timber which will affect the rate of drying, but this was not investigated.

It has become increasingly evident that the time required for natural seasoning is not nearly so long as usually stated, and

hence a good deal of doubt is thrown upon the advisability of artificial seasoning on a large scale. Temperature and Circulation of Air are the two main factors in seasoning. But in the manner in which green timber is stacked in the timber yards there is no circulation of air in the stack, and hence drying can only go on from the ends, and these tend to crack badly. As timber dries by diffusion, then in such a stack the moisture must diffuse out from the ends, and hence it is no wonder that hardwood is said to be a slow timber in drying. If timber be filleted in the stack, that is if cross pieces are laid, some distance apart, across each layer of timber, and the next layer stacked on these, then there is an opportunity for circulation of air, and the winds would be responsible for this.

A stack of 6 fts. of 6 x 1 Mountain Ash was made in the laboratory, and fillets were placed between each layer. The boards are drying rapidly, but are not yet finished. The full results will be given in a paper to be published later, when a further test has been made outside with a larger stack.

The boards have dried rapidly, and a typical case is given below :—

Date.		Weight.		Percentage Lost.
9.11.18	...	16 lb. 6 oz.	...	0
29.11.18	...	11 lb. 2 oz.	...	32.1
16.12.18	...	9 lb. 14 oz.	...	39.7
8.1.19	...	9 lb. 10 oz.	...	41.2
20.1.19	...	9 lb. 10 oz.	...	41.2

It will be seen that in two months the timber lost 41.2 %, and this must be regarded as very satisfactory.

During the summer and autumn Melbourne has ideal conditions for natural seasoning if the timber be properly stacked.

To be able to get the moisture content of timber readily is important, and Professor Laby suggested there might be a relation between moisture content and electrical resistance. The present method of finding the moisture content is not readily available for commercial use and therefore some simple method is necessary. The resistance was measured by a Megger. It was found necessary to plane up the surfaces of the timber to be tested, as the dry exposed faces greatly increased the resistance. The results are given in Fig. 7.

It will be seen that there is a close relation between moisture content and resistance. To be of any value, further experiments are necessary with regard to the direction in which the resistance is measured, species of timber, density of specimen, etc.

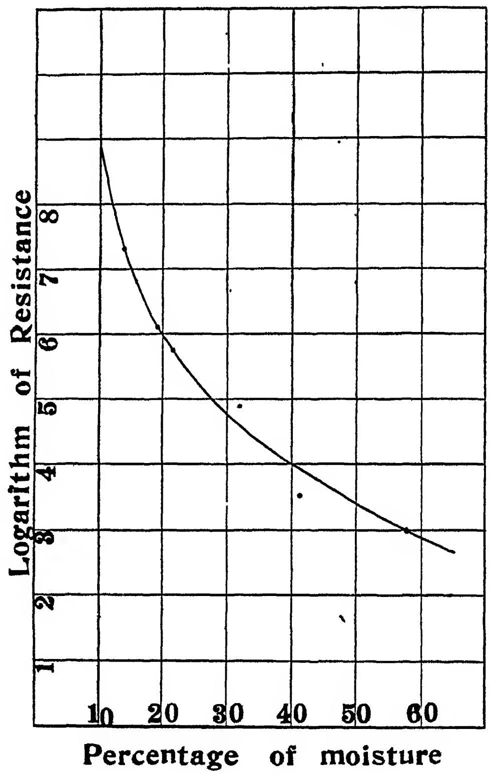

Fig. VII.

Structure.—Only a few notes on the structure of Mountain Ash will be given, as a comparative study of the structure of our timbers is being carried on. The outstanding feature is the simplicity of its structure which in this respect is comparable to pine. The most notable feature is the area given over to water conduction. The vessels are elliptical, the major axis being directed radially. The largest major axis recorded is 0.4 mm., and the average works out at 0.253 mm. An interesting feature is the distribution of the vessels over the annual ring. They are not confined to the spring wood. A few experiments were made to determine the lengths of the vessels by the mercury method. It

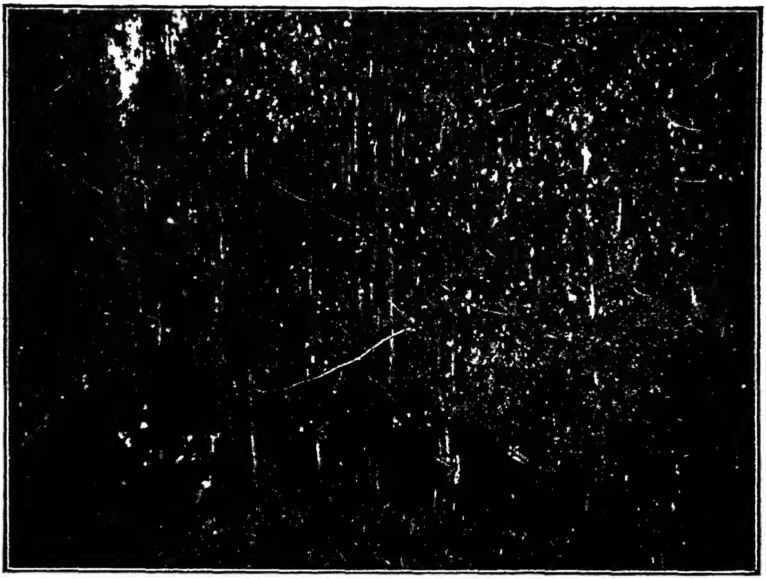

Fig. A.—Very dense young forest of Eucalyptus regnans. Age 2 to 4 years.

Fig. B.—Mature forest of Eucalyptus regnans, averaging 39 trees per acre. Tallest tree 261 feet.

was found that a portion of a sapling ·1⅛ in. in diameter and 6 ft. 1½ in. long had 31 vessels as long as the piece itself. This result is not as good as some given by Professor Ewart in Annals of Botany, 1910, but it is very likely that even these results could be beaten by Mountain Ash. The length of the vessels, their large size, and their even distribution over the annual ring will probably limit the application of Mountain Ash for certain purposes.

The second element of importance is the libriform fibres. They are elongated and sharply pointed. They average about 1 mm. in length. It would appear that the fibres formed during the sapling growth are slightly longer than those formed in later years. Haberlandt states that the reverse is the case for tracheides in conifers.

The rays are uniseriate and very numerous. In the rays in the centre of old mature trees nuclei are very frequent. These have been traced almost up to the central ring, so that they must be considerably over a century old. No trace of starch has been found in these central ray cells. In conjunction with this phenomenon is the fact that this central wood has a higher moisture content than the rest of the wood. This high moisture content accounts for the enormous shrinking and warping that takes place when this central wood or "heart" dries. This large percentage of moisture in the centre, together with the imperfect lignification of the fibres predisposes the central portion to decay. By good forestry the amount of this immature wood formed could probably be lessened.

Tyloses have frequently been found associated with the nuclei near the centre of the big timber. Tyloses have also been abundantly found in Messmate (E. obliqua), right up against the cambium. These facts are conflicting, and at present no explanation can be given.

Mountain Ash when green is a softwood, but when seasoned is a hardwood, and this must be kept in mind if this wood is to be pulped. A very objectionable feature to its use for pulp is the presence of tannin.

I wish to express my thanks to the various sawmillers and bushworkers who have kindly afforded opportunities for carrying out these investigations. My thanks are especially due to the manager of Powelltown.

The work was carried out in connection with the Botanical Laboratory, Melbourne University, with the aid of a Government Research Grant.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919

Art. XIX.—*The Sand Ridges, Sand Plains and "Sand Glaciers" at Comet Vale in Sub-arid Western Australia.*[1]

By J. T. JUTSON

(Formerly of the Geological Survey of Western Australia).

(With Three Text Figures).

[Read 12th December, 1918].

Introduction.

Comet Vale is a mining township 1236 feet above sea level, and 63 miles north of Kalgoorlie, on the railway from Kalgoorlie to Leonora. The district forms part of the great sub-arid plateau in south-central Western Australia, where the rainfall is probably under 10 inches per annum. There is a notable quantity of blown sand in the district, and the distribution of this sand throws considerable light on the action of the wind in the formation of certain types of country.

Summary.

At Comet Vale blown sands are widely distributed and are associated with other types of country, namely, deeply dissected "high" lands, and the "dry" lake or playa, Lake Goongarrie.

The blown sands from sand ridges, sand plains and "sand glaciers." The ridges are mostly parallel to one another and are approximately east and west in general direction. They rest upon the sand plains.

At the township of Comet Vale the sand forms a smooth and unbroken surface with a gentle fall to the west. The sand is wind-borne and has spread steadily up the flanks of a laterite ridge to the east, and in some instances has climbed the passes or saddles of the ridge, thence widening out on the opposite (eastern) side of the ridge as "sand glaciers."

The sands have been derived from extensive sand areas to the west, and are marching eastwards. The dominant winds are apparently westerly.

In its march eastwards, the sand has blotted out the drainage lines west of the laterite ridge; and east of such ridge, the courses of various small intermittent streams from the "high" lands have been diverted.

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1 By permission of the Acting Government Geologist.

The occurrence of a smooth, unbroken, sloping plain of sand, which has been formed by wind action, is important as probably throwing light on the occurrence of sand plains elsewhere in sub-arid Western Australia.

The Chief Physical Features of the District.

(1) To the east of the township there is a belt of "high" lands which has two main divisions, as follow:—(a) A north-north-west-trending belt which has been dissected into various ridges of

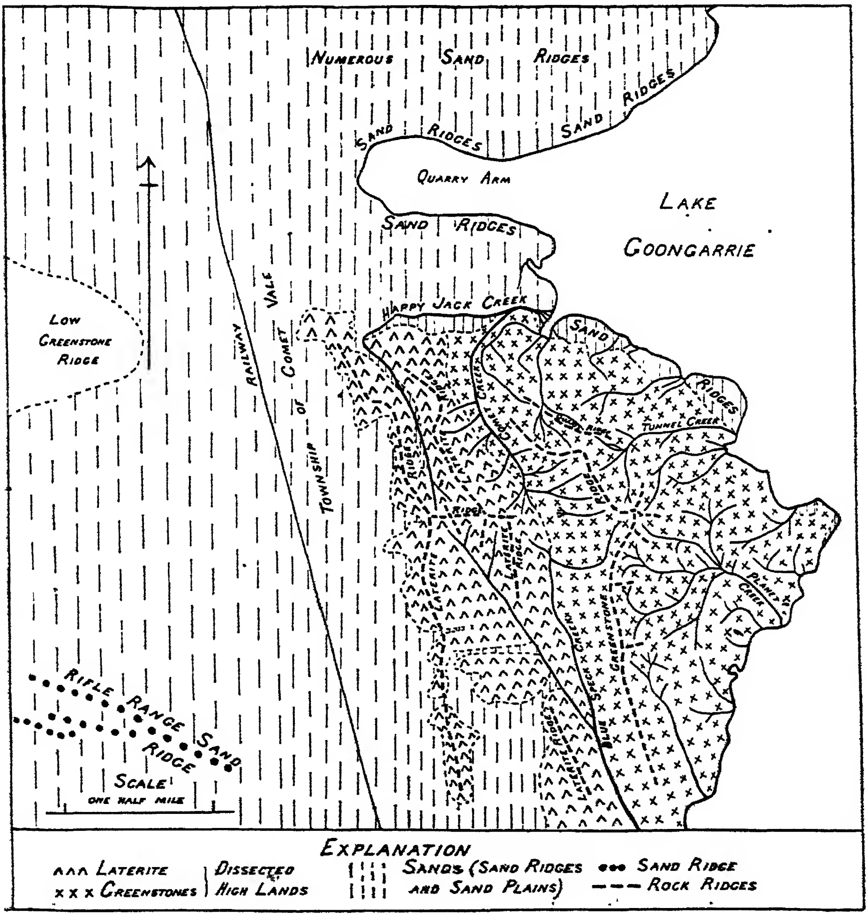


Fig. 1.—Physiographic Map of Comet Vale. *Note.*—A belt of alluvium occurs along the floor of the Blue Speck Creek valley. This has not been shown on the map.

ferruginous laterite, the chief of which is a ridge bearing north-north-west on the western side of the belt. The latter is separated on the east from the area now to be described by a deep, but mostly wide, open valley. (b) A belt of greenstone lying to the east of (a) and bounded on the east by the "dry" lake or playa, Lake Goongarrie. This belt is deeply dissected by narrow V-shaped radial valleys in the adolescent or early mature stage. The crests of (a) and (b) are about 100 feet above the floor of the lake.

(2) Lake Goongarrie forms an extensive "dry" lake or playa, having on its western shore greenstone cliffs which form part of (b), and having on its northern and north-eastern shores sand ridges.

(3) Gently undulating sand plains lie to the west, north and north-west of the township, and on these plains rest sand ridges of varying height (the highest probably being 50 or 60 feet above the plains) and having an approximately east and west trend. The sand plains are broken by occasional small "dry" lakes. No watercourses exist in this belt, as the sand immediately absorbs the rain. Just to the east of the railway the sand overlies a rather coarse ironstone "wash," a few feet thick, which in turn overlies the bedrock, greenstone.

Vegetation of the Sand Plains and Sand Ridges.

Slight differences exist between the vegetation of the sand plains and that of the sand ridges.

On the sand plains there are two types, which may be termed the acacia type and the eucalyptus-"spinifex" type, the acacias or the eucalyptus and "spinifex" predominating as the case may be. The eucalypts are of the stunted branching-from-the-root type known as "mallee" eucalypts. The two types may in places more or less merge into one another, but over considerable areas they are substantially distinct.

On the sand ridges the vegetation can hardly be divided for the purposes of this paper into distinct types, but some characteristics may be noted. The mallee eucalypts grow on the sides of some ridges, but usually cease before the top is reached. The acacias may grow both on the top and sides, and likewise the spinifex; but as a rule spinifex and acacias are not commonly found together. The tops of the ridges may be destitute of tall shrubs and trees, and in this case the spinifex usually grows, associated with low, often sprawling shrubs.

The vegetation as a whole is stunted and xerophytic, and there is much bare ground between the plants.

Nature and Distribution of the Blown Sands.

The blown sands of the district may be divided into (a) sand plains, (b) sand ridges or dunes, and (c) "sand glaciers."

(a) The *sand plains* cover large areas to the west and to the south of Comet Vale. They may be almost level or undulating. The township of Comet Vale is largely built upon a sand plain which slopes gently downward with a smooth and unbroken surface to the west from the western flanks of the north-north-west trending laterite ridge immediately to the east of the township. The sands of the sand plains are generally fine-grained and consist mostly of quartz. They contain a certain amount of fine material which tends to make the surface somewhat firm. The surface is thus composed in places of what might be termed a loamy sand.

(b) The *sand ridges or dunes* are numerous, and occupy considerable space to the west and to the north of Comet Vale. A prominent ridge, which the writer has named the Rifle Range Ridge, lies to the south-west of the town; and on both the northern and southern sides of the Quarry Arm of Lake Goongarrie, steep ridges rise from the edge of the lake. For about four miles northwards from the township the railway cuts through many.

The ridges have sides varying in slope from steep to gentle, and rise from the sand plain to a maximum height of about 50 or 60 feet.[1] They are roughly parallel to one another and have a general east and west trend, with variations towards west-north-west and towards east-north-east. If the westerly winds be the dominant ones, as they appear to be, the ridges are longitudinal.

The ridges vary in their distances apart, some being practically isolated, and others within a quarter of a mile of one another. Some reach a length of over half a mile. Fine well-rounded grains of quartz and ironstone, the quartz predominating, form the sands of the ridges, and the surface layers at least seem to be free from the finer material, which no doubt has been blown or washed out from the sand. Between the ridges the sand is mixed with finer material, as already mentioned when describing the sand plains.

Some of the ridges are compound ones, being forked, with two or more branches. The Rifle Range Sand Ridge towards its western

1 Some elevated irregularly shaped areas of blown sand have long gentle slopes and, in some cases, flat tops. They are apparently due to some local phase of wind action, but they are not further discussed in this paper.

end breaks into three branches which are separated by troughs a comparatively few feet deep. The bottoms of these troughs are well above the surrounding sand plains, so that they are part of the ridge. Between two of these branches there is a distinct roughly circular basin in the sand having a diameter of about 30 or 40 yards and a depth below the rim of perhaps 25 feet. This is the type described by Cornish[1] as a fulj.

(c) The typical forms of sand accumulation known as "*sand glaciers*," which have been described in various parts of the world are due to sand being blown up the sides of hills or mountains, thence finding a passage through any passes or saddles, and spreading out on the opposite sides to form wide fan-shaped plains. This is Free's definition.[2] Cornish[3] restricts the term to a horizontal plateau of sand terminated by a talus, as steep as the sand can rest. The forms at Comet Vale are, on a small scale, closely related to those referred to by Free; hence the present writer retains the term as a convenient one.

Immediately to the east of the town is a north-north-west trending ridge of laterite forming part of the laterite high lands previously referred to. This ridge is cut into by amphitheatres, which form the heads of the small watercourses which formerly extended westward; and it also has several comparatively low passes or saddles. The lower western flanks of the ridge have a smooth unbroken sloping sand plain with a gentle but still a definite fall to the west. Artificial openings, such as mining shafts and costeans, show that the sand of this plain is here from a few inches to about ten feet in depth, and that it is fine-grained, well-rounded and homogeneous. It shows, however, no planes of stratification, but would probably do so if it became consolidated and subsequently weathered out. Below the sand there is a deposit from one to six feet thick, made up largely of angular fragments, up to three or four inches in size, of laterite, similar to that of the laterite ridge referred to above. This material is evidently derived from such ridge and represents the debris spread over the surface before the sand drifted up the slope, the carrying of such rock waste no doubt being due to the occasional tiny streams which ran from the amphitheatres above described, and to the fact that such waste always tends to drift by gravitation from higher to lower slopes.

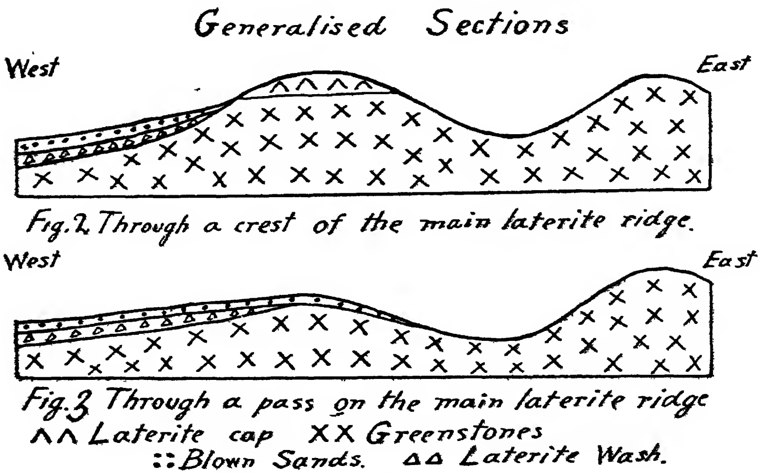
1 Cornish, V.—"On the Formation of Sand Dunes." Geog. Journ., 1897, pp. 295-298.

2 Free, E. E.—"The Movement of Soil Material by the Wind." U.S. Dept. of Agric., Bureau of Soils, Bull. No. 68, Washington, 1911, p. 57. (Footnote *a*).

3 Op. cit., p. 286.

Below this laterite waste, the bedrock of greenstone (a fine-grained epidiorite or amphibolite) occurs. The sand can be traced to some of the saddles of the ridge, through which it has passed, and spread itself outward and downward on the eastern sides of the ridge. Towards the northern end, the sand on one saddle has become discontinuous, by erosion of some kind, with that lower down on the eastern slope of the ridge, where it is now being removed by stream action. Towards the southern end, at another saddle, a small amount of sand has spread well over the saddle, but has not, as a blown sheet, reached far down the eastern slope, as it is being carried away by a small watercourse, along which it forms a narrow thread. Still farther south the sand has spread out as a wide, long mass and has merged into that which has worked around the eastern side of the ridge from the sand plain to the south of this ridge. Stream action has carried portions of this sand farther east as narrow bands. Where the ridge is higher than the passes, the sand flanking the ridge on its western side is at a lower level than that at the passes. The outline of the sand at its junction with the laterite thus shows a series of curves rising in height as the passes are approached.

These deposits of sand, which are clearly wind-blown, constitute, on the eastern side of the laterite ridge, the "sand glaciers" of Comet Vale, and this paper is, so far the writer is aware, the first record for such phenomena in Western Australia.



Figs. 2 and 3.—Generalised sections across the sloping sand plain and the dissected high lands, showing the relation of the sand to the crests and passes of the main (western) laterite ridge.

Effects of the Sand on the Topography.

The effect of the spread of the sands has been to divert some of the present small stream courses at Comet Vale and to blot out the drainage to the west of the same place, as there is evidence of a wide north-south valley there, which must have been a drainage line before the sands spread across and choked it. The water courses which originally ran westward to this old valley from the laterite ridge have also been smothered. The general result is the substitution of the sand ridges and sand plains for the old fluvatile topography.

Significance of the Sand Distribution as to the Work of the Wind in this and other Areas

The numerous sand ridges of the district show that the wind has removed a very large quantity of sand, and hence its influence on the general erosion of this portion of the country must be considerable.

The most important sand distribution of the district, however, is the belt of sand on which the township of Comet Vale stands. This has already been described as a gently-sloping sand plain on the western flanks of the laterite ridge, and falling westwards. This sand belt, as also shown above, passes over the saddles of the ridge and then into the "sand glaciers." The sand on the western flanks of the ridge is wind-blown beyond question. There are no rocks at the ridge or thereabouts that could have provided the material; the sands, as seen in artificial sections, are remarkably homogeneous in texture and materials; the waste from the laterite ridge lies buried beneath the sands; and the sands are continuous with the wide sand area to the west. These facts, together with the distribution of the sand up the flanks of the hills, through the passes and thence on the opposite side of the ridge as "sand glaciers," leave no doubt as to the wind origin of the sand.

That being so, there exists a sand slope, smooth and unbroken by sand ridges, and to all intents a sand plain; and this sand plain has been formed by the wind. Sand plains are of wide occurrence in inland Western Australia, and although the wind was thought to be an important agent in their formation, direct evidence as to its action is not always obtainable. The Comet Vale evidence may help to determine the matter, although of course each area must be independently investigated. It, however, suggests

that many of the other sand plains of inland Western Australia may be at least partly of wind origin.

A somewhat parallel case occurs at Goongarrie, a mining township 8 miles to the south of Comet Vale. The township is situated on an unsymmetrical ridge the western side of which has a gentle unbroken slope, but the eastern side is represented by a line of low cliffs cut into small canyons by the short watercourses (almost always dry) which trend eastward to a small southward-trending valley. The rocks of the ridge are serpentines and hornblendites, but the western slope is covered (only, however, to a depth of about six inches) by fine quartz sand of the origin of which no other explanation can apparently be given than that it has been blown by the wind from the west up the slope. There are greenstone hills a little farther west, and beyond these extensive sand plains. The sand could be, and probably has been, blown from the sand plains through a gap in the greenstone hills opposite to the unsymmetrical ridge now referred to. An interesting point is that portions of the sand on the western slope have been blown over the crest of the ridge into the heads of the eastward-trending watercourses above described, and that stream action is carrying it to the lower portions of the valleys. Wind action on the western slope has probably been accelerated by the removal of a considerable portion of the native vegetation.

An unbroken sloping plain of wind-blown sand remarkably parallel in certain points to the Comet Vale and Goongarrie examples, although on a much greater scale, has been described by Ball[1] in West-Central Sinai. The plain of Debbet el Qeri rises gradually to the south, due to the prevalent northerly winds carrying the sand along, with a gradual overflow into the heads of the deeply-cut wadis draining southwards; the present tendency of the sand is to move southwards and choke the heads of the wadis. The sand is covered with scattered bushes, and its surface was level enough to be used for the base line of Ball's triangulation.

Direction of Past and Present Drift of the Sands.

The distribution of the blown sands suggests that they have drifted easterly and that the dominant winds therefore have been from the west. From limited observations made by the writer in

1 Ball, J.—"The Geography and Geology of West-Central Sinai." Survey Department, Cairo, Government Press, 1916, pp. 87-88, 115.

the Comet Vale district in the summer of 1916-1917, and the early part of the winter of 1917, the present dominant winds also appear to be westerly, and this is confirmed by observation of blown sand in regard to the so-called "spinifex" plant, the direction of inclination of certain trees, and the movement of the sand along the railway line where the removal of the vegetation has allowed the sand to move more rapidly than it otherwise would do.

[Proc. Roy. Soc. Victoria, 31 (N.S.), Part II., 1919].

Art. XX.—*The Sensitiveness of Photographic Plates to X-rays.*

BY

NATALIE C. B. ALLEN, B.Sc.,

AND

T. H. LABY, M.A.

(Professor of Natural Philosophy in the University of Melbourne).

(With Four Figures in the Text).

[Read 12th December, 1918].

This work was undertaken in order to determine the relation existing between the exposure and the resulting optical density of a plate exposed to X-radiation, and the type of plate most suitable for radiographic work. On the first question (the relation between exposure and density) work had previously been done by Salomonson[1] and by Hodgson.[2]

The plates under investigation were given a known exposure, developed in a standard manner and their densities were measured by a polarisation photometer.

For generating the X-rays a Coolidge tube excited by an induction coil was used, the potential across the tube being regulated by adjusting the length of the alternative spark-gap of the coil until a spark passed occasionally.

It was assumed that the exposure was proportional jointly to the energy of the X-radiation and to the time of exposure. The corresponding law for light is the Bunsen-Roscoe reciprocity law that, for equal densities of the photographic plate, the product I.t of intensity of light and time of exposure is constant. This law is not correct, and has been replaced by the Schwarzschild law that $I.t^p$ is constant for equal densities. The value of the constant p depends on (1) the kind of plate used, (2) the development,[3] (3) the density of the plate, and (4) the colour of the light used.[4] Stark[5] proposed the formula that $k.I.^m t^n$ is constant for equal densities, where k, m, n are constant for small variations of I. and t. Kron[6]

1 Salomonson. Proc. Amsterdam Acad. xviii, 1916, p. 671.
2 Hodgson. Amer. Journ. Roent, 1917, p. 610.
3 Koch. Ann. d. Phys., iv., 30, 1909, p. 841.
4 Parkhurst. Astrophysikal. Jour., 30, 1909.
5 Stark. Ann. d. Phys., iv., 35, 1911, p. 461.
6 Kron. Publikationen des Astrophysikalischen Observatoriums zu Potsdam, No. 67, 1913.

tested the Schwarzschild law over a wide range of intensities, and found it to hold only for extreme values of the intensity. For a certain range of intensity he found the Bunsen-Roscoe law to be true.

Experiments were made in order to test the truth of the assumption that, when the product of energy of X-radiation and of time of exposure was constant, the photographic effect is the same. The energy of the X-radiation is, with the other conditions constant, proportional to the current flowing through the tube. The two halves of a plate were exposed separately; the current for the second exposure was 1/100 of the current for the first exposure, the time of exposure being correspondingly increased to 100 times its original value. After development it was found that the densities of the two halves of the plate were widely different, showing that the product of energy of radiation and of time of exposure does not determine the density.

In the small range of currents used in this work, however, (from .03 to .06 milliampere) the statement that density is jointly proportional to the energy of radiation and to the time is approximately true. This conclusion is verified by measurements made by Kröncke.[1] His results are shown below :—

Current	-	1.0	-	2.0	-	3.0	-	4.0	milliamperes.
Time	-	12.0	-	6.0	-	4.0	-	3.0	minutes.
Density	-	1.09	-	1.15	-	1.16	-	1.15	

The energy of the cathode-rays is jointly proportional to the current flowing through the tube and to the electrical pressure applied to the tube. The fraction of this cathode-ray energy converted into X-ray energy in the Coolidge tube is proportional to the square of the velocity of the cathode-rays, i.e., to the first power of the pressure.[2] Hence we define exposure in radiography as

$$e^2ct/d^2 \text{volt}^2.\text{ampere.sec.cm}^{-2}.$$

where, e volts = pressure applied to tube.

c amperes = current through tube.

t seconds = time of exposure.

d cms = distance from source (anticathode) to plate.

The average current was measured by an unshunted milliammeter connected in series with the tube and induction coil. The cathode of the tube (to which the milliammeter was connected) was earthed. The time of exposure was measured by a stop-watch.

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1 Kröncke. Ann. d. Phys., iv., 43, 1914, p. 687.

2 Rutherford and Barnes. Phil. Mag., xxx., 1915, p. 361.

Each plate was exposed in from five to eight strips, the exposures of successive strips increasing in a constant ratio. There was also a fog-strip which was shielded from radiation the whole time.

The distance from plate to anticathode was 100 cms. The currents used varied from .03 to .06 milliampere. The pressures used were 31.5, 73.0, 83.0 kilovolts corresponding to spark-gaps of 1.5, 5.0, 7.0 cms., respectively between spheres of 6.5 cms. diameter, the cathode being earthed.[1] The minimum wave-lengths of the radiation were, therefore, $.390 \times 10^{-8}$, $.173 \times 10^{-8}$, and $.152 \times 10^{-8}$ cms. respectively.[2] The wave-lengths of the K and L characteristic radiation for silver are $.56 \times 10^{-8}$ and 4.17×10^{-8} cms., and for bromine 1.05×10^{-8} and 8.48×10^{-8} cms.

The developer was one often used in radiography, as follows[3]:—

Solution A.

Hydroquinone	25 gms.
Potassium metabisulphite	25 gms.
Potassium bromide	25 gms.
Water	1000 c.c.

Solution B.

Potassium hydroxide	50 gms.
Water	1000 c.c.

The two solutions were mixed in equal proportions immediately before use, and the plates were developed at a temperature of 20° C. for 4 minutes. After 4 minutes' development the density due to the exposure had reached its maximum value and further development only increased the fog-density of the whole plate. In order to verify this an Ilford X-ray plate was cut into three pieces, which were exposed simultaneously. On each piece there was a strip which received an exposure of 8.7×10^3, one which received 4.1×10^4 volt.[2] amp. sec. cm^{-2}, and an unexposed or fog strip. The three plates were then developed at 20° C. for periods of 3, 4, and 5 minutes respectively. The resulting densities are tabulated below under D_1 and D_2, which are the densities due to the exposures given, the fog-density, D_f, having been subtracted from the measured density.

1 F. W. Peek. "Dielectric Phenomena in High Voltage Engineering," p. 89.
2 Hull. Phys. Rev., vii., 1916, p. 156.
3 Sahni. Phil. Mag.; xxix., 1915, p. 836.

Time of Development.	D_1	D_2	D_f
3 minutes	1.83	2.49	.37
4 minutes	2.52	3.42	.45
5 minutes	2.57	3.56	.58

Evidently, after 4 minutes' development, the density due to any exposure does not appreciably increase, though prolonged development does increase the fog-density.

The transparency of a plate is defined as the ratio of the intensity of the transmitted light to that of the incident light, i.e. $T = \frac{I_t}{I_i}$ The opacity, O, is the reciprocal of the transparency, and the density, D, is defined thus:—

$$D = \log_e O = \log_e \frac{I_i}{I_t}$$

A polarisation method was employed in measuring the density. Light from the source S was reflected from the plane mirror M, and was viewed through O, where it illuminated half of the field of view. The other half of the field was illuminated by light from S^1, which had been transmitted through a pair of Nicol prisms. Metallic filament lamps in parallel were used as the sources of light.

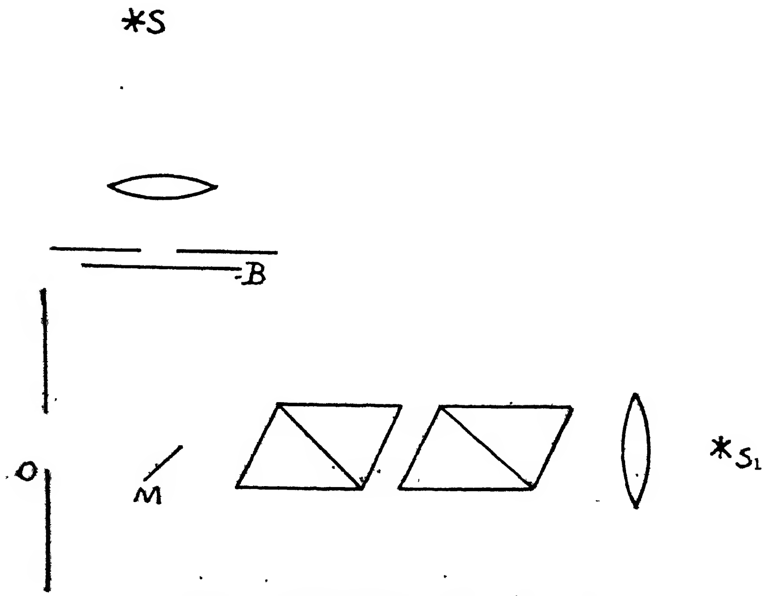


Fig. 1.—Polarization Photometer.

A plate of green glass was placed in the path of each beam of light so as to eliminate any difficulty due to difference of colour in the two halves of the field of view. The analysing Nicol was rotated until the two halves of the field of view matched; the angle θ between the two Nicols was read, and the intensity of the light from S was therefore proportional to $\cos^2\theta$. The photographic plate B was now placed in position, and the analysing Nicol was rotated until the field again appeared uniform. If the angle between the two Nicols was now θ', the intensity of the light transmitted through the plate was proportional to $\cos^2\theta'$. Hence the density of the plate was obtained as $\log_e\frac{I_i}{I_t}$, or $\log_e\frac{\cos^2\theta}{\cos^2\theta'}$. The density of the fog strip was also measured and was subtracted from the measured density of each of the other strips to give the true density due to the exposure.

When, for any given plate, the density was plotted against the logarithm of the exposure, the curve obtained was similar in character to that for light. In the region of under exposure the curve was convex to the axis of log E (see Fig. 2), but for densities greater than about 1.0 a straight line was obtained, so that in this neighbourhood the density of a plate is given by $D=\gamma.\log_e\frac{E}{i}$. The quantity i is the inertia of the plate, and is the exposure corresponding to the density of 0 if the straight line law held for all

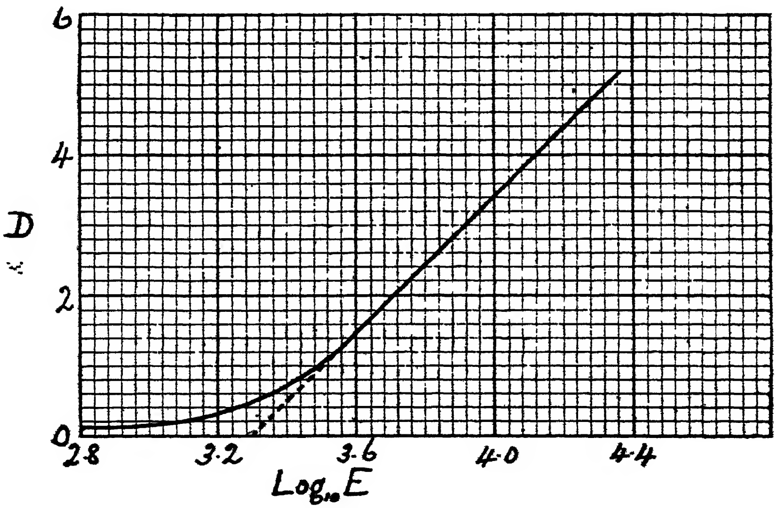


Fig. 2

values of the exposure. For the exposures we have used we find that the inertia of a plate is independent of the time of development. In the table below, D_1 and D_2 are the densities resulting from exposures of 8.71×10^3 and 4.10×10^4 volt^2.ampere.sec.cm^{-2} on Ilford X-ray plates.

Time of Development.	D_1	D_2	D_2/D_1
3 minutes	1.83	2.49	1.36
4 minutes	2.52	3.42	1.39
5 minutes	2.57	3.56	1.36

Since the ratio D_2/D_1 is independent of the time development, it follows that the exposure corresponding to a density of o, i.e., the inertia, is independent of the time of development. Hurter

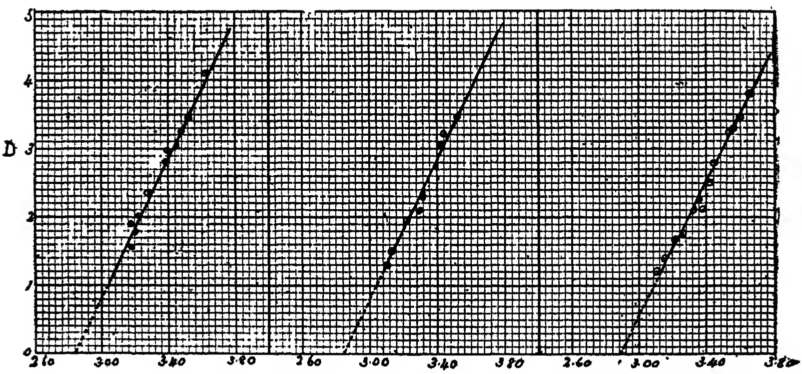


Fig. 3

and Driffield[1] have proved it to be independent also of the kind of developer used. The so-called speed of a plate is a quantity inversely proportional to the inertia.

γ, or the increase in D corresponding to an increase of 1 in $\log_e E$, is the contrast of the plate. Its value depends on the development, and reaches a maximum when the plate has been developed to its maximum density.

In the table below are tabulated (1) the inertia of the plate (in volt^2.ampere.sec.cm^{-2}), (2) the contrast, and (3) the minimum value obtained for the fog density.

1 Hurter and Driffield. Jour. Soc. Chem. Ind., 9, 1890, p. 455.

	Plate.	Inertia.	Contrast.	Fog-density.
1	Paragon X-ray	1.17×10^{-3}	2.4	.59
2	Paragon X-ray	.74	2.3	.23
3	Diagnostic X-ray	.71	2.2	.30
4	Sunic X-ray	1.00	2.3	.60
5	Seed X-ray	1.12	1.9	.45
6	Wratten X-ray	1.95	2.2	.51
7	Wellington X-ray	1.70	2.0	.24
8	Austral X-ray	4.68	3.1	.40
9	Imperial X-ray	1.26	1.6	1.44
10	Cramer X-ray	2.14	1.9	.55
11	Ilford X-ray	2.19	1.9	.36
12	Imperial Special Rapid	1.44	1.5	.18
13	Imperial Special Sensitive	.81	1.3	.38
14	Austral Standard (Sun)	1.58	1.4	.27
15	Austral Standard (Extra Rapid)	3.71	1.2	.35
16	Austral Standard (Extra Rapid) II.	1.23	1.2	.59

Although all the Paragon X-ray plates used were from the same batch, two distinct exposure lines were obtained, both giving the same contrast, though the inertia was much greater in one case than in the other. Apparently, some of the plates had received a thicker coating of emulsion than others.

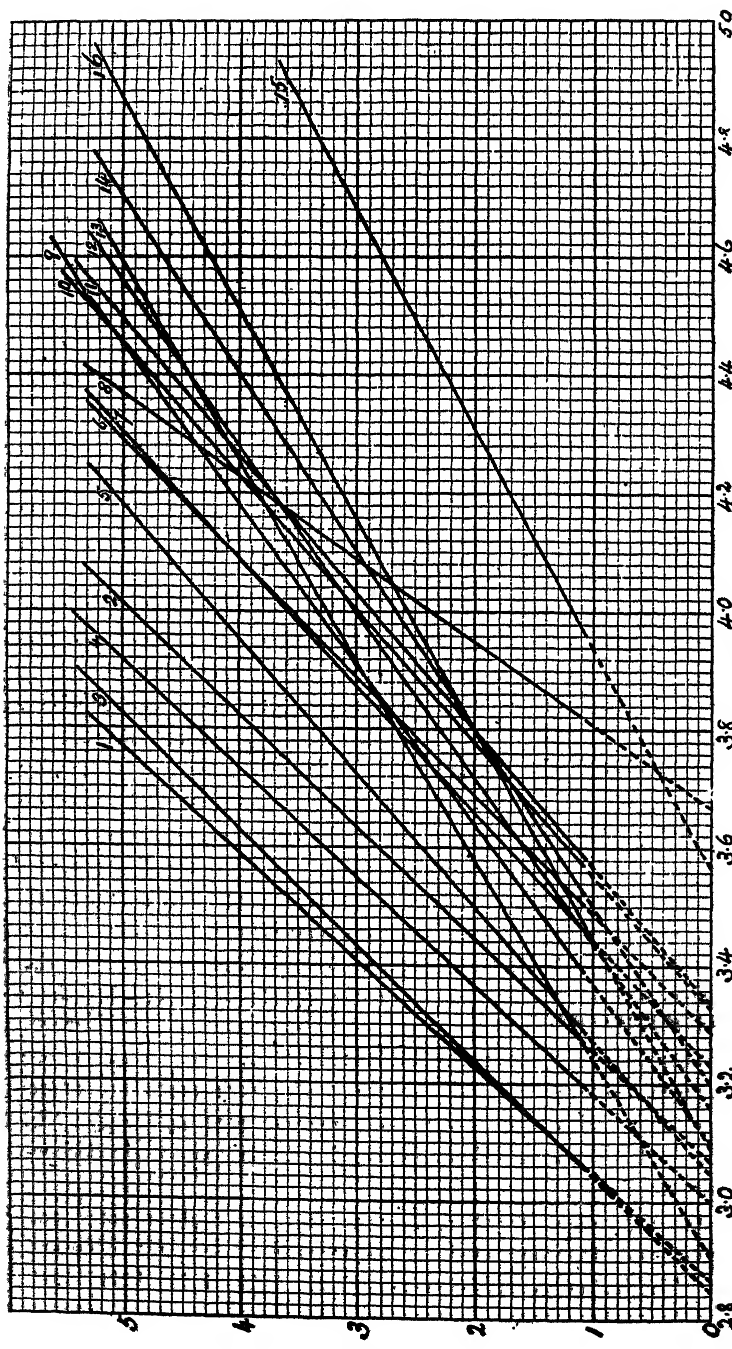
Salomonson[1] found that, while the inertia of any given type of plate was always the same, whatever the hardness of the rays, the slope of the exposure line and, therefore, the contrast of the plate, was greater for the more penetrating radiation. Hodgson,[2] on the other hand, found in his measurements of the density of Seed X-ray plates, that the contrast diminished with the increasing hardness of the radiation. In this work, however, the exposure lines for the three different pressures, that is for three different wave lengths, were found to be coincident. The inequalities in the thickness of the emulsion on the plates are more than sufficient to account for any departures from the straight line. The actual points obtained with the Diagnostic X-ray plate for each of the three pressures used are shown in the graph Fig. 3; the three exposure lines are coincident within the limits of accuracy possible.

The accuracy of the results is limited by the variations in the thickness of the emulsion on the plate. In some cases variations even in the small strips being photometered were noticeable. In order to find the magnitude of errors due to this cause the following tests were made:—

(1) An unexposed Wratten X-ray plate (half-plate size) was developed and the fog-density was measured at eight different points. The values obtained were:—1.62, 1.56, 1.62, 1.83, 1.82,

1 Salomonson. Loc. cit.

2 Hodgson. Loc. cit.



D
0
1
2
3
4
5
$Log_{10} E$
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
1
2
3
4
5
8
9
10
11
12
13
15
16

Fig. 4

1.63, 1.85, 1.71; the average departure from the mean value of 1.71 was .10.

(2) A Paragon X-ray plate (size 10 in. x 8 in.) was given an exposure of 2760 volt^2-ampere-seconds per cm.^{2} After development its density was measured at twenty points, the values obtained being:—3.58, 3.94, 4.08, 4.21, 4.73, 4.73, 4.59, 4.33, 4.14, 3.74, 4.08, 4.21, 4.14, 3.50, 4.04, 4.21, 4.59, 3.50, 3.91, 4.08; the average departure from the mean value of 4.12 was .26.

Direct measurements of the mass of silver salts per square centimetre of each plate verified the existence of these inequalities.

Mr. Jones, of the Kodak (Australasia) Ltd. kindly prepared plates of the same type as the Austral Standard (Extra Rapid) plates, but having a double coating of emulsion. This plate is tabulated as Austral Standard (Extra Rapid) II. As can be seen from the exposure lines, this led to an increase in speed, though the contrast remained practically unaltered. Unfortunately, however, the fog-density was also increased, and, as the plate was always somewhat stained by the developer, it was difficult to measure its density.

In obtaining the mass of silver salts on the plate, the emulsion, after having been dissolved off in boiling water, was digested in nitric acid and filtered through a Gooch crucible. Two measurements were made for each plate and the differences between the values obtained confirmed the existence of inequalities in the thickness of the emulsion. The total mass of emulsion and gelatine together was also measured, and the percentage of silver salts in the emulsion was calculated.

The table below gives the two values obtained for the mass of silver salts per unit area of the plate, and also the average value of the percentage by mass of silver salts in the emulsion. From these figures it appears that the speed of a plate does not depend entirely on the mass of silver present in the emulsion:—

Plate.	Mass of Silver Salts per cm^2.		Mass of Silver Salts per 100 mgms. of Emulsion.
	1	2	
	mgms.	mgms.	mgms.
Paragon X-ray	2.4	2.6	48
Wellington X-ray	2.2	2.4	39
Wratten X-ray	2.5	2.6	38
Ilford X-ray	2.4	2.6	45
Imperial X-ray	3.2	2.9	38
Austral Standard (Sun)	1.3	1.5	—
Austral Standard (Extra Rapid)	1.0	.8	29
Austral Standard (Extra Rapid) II.	2.5	2.9	45

SUMMARY.

1. Exposure in radiography is defined as energy of incident X-rays per square cm.

2. It is found that within a limited range of exposure the density of the developed "image" produced in a silver emulsion is proportioned to the logarithm of the exposure.

3. The density of the image produced by a given quantity of incident energy is independent of the wave length of the radiations used in these experiments.

4. The inertia, contrast, and fog density of a number of plates for low radiation intensities is stated.

5. The speed (that is, the exposure required to produce a given density) of a plate depends on the nature of the emulsion, and the mass of silver per unit plate area.

6. Contrast depends on the nature of the emulsion and is apparently independent of the mass of silver per unit area.

The experiments are being continued.

INDEX.

The names of new genera and species are printed in italics.

END OF VOLUME XXXI.

[PART II. PUBLISHED MAY, 1919.]

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1920.

CONTENTS OF VOLUME XXXII.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. I.. 1919].

ART. I.—*The Origin of the Volcanic Tuff of Pejark Marsh Victoria.*

BY R. HENRY WALCOTT
(Curator, Technological Museum).

[Read 8th May, 1919].

In view of the discovery of a native implement associated with fragments of bones of extinct marsupials under volcanic tuff at Pejark Marsh, near Terang, by Mr. A. J. Merry,[1] increased interest is attached to the task of ascertaining the probable age and origin of the tuff.

For this reason the opportunity was taken, while supervising some excavations being made at the Marsh, in 1909, in search of further evidence of man's antiquity, of paying a few hurried visits to various places in the neighbourhood likely to bear upon the subject. The following notes are principally the result of information so gained, but, as the time devoted to field investigation was unavoidably very limited, they must of necessity be brief, and perhaps omit some matter of value in deciding the issue in question.

An account of the excavations referred to, and of the occurrence of the tuff has already appeared.[2] It might be mentioned here, however, that the tuff is seen as a fine-grained bedded deposit, from 15 to 24 inches thick, along a drain made to carry the water away from the Pejark Marsh. The tuff has been laid down in an old swamp, now represented by a stiff, black clay bed, and abundant leaf impressions are present in the lower layers of the tuff. Resting on the tuff again, comes the heavy, black soil of the present marsh, some two or three feet in thickness.

The tuff is locally known as "sandstone," and is also called "sandstone tuff," on the quarter sheet No. 8 N.E. (New Series), of the Geological Survey of Victoria.

Previous reference to the deposit has been made by Professor J. W. Gregory,[3] when he states: "The broad down-shaped hill to the south-west of Camperdown, and the plains between Terang and Noorat, are formed of re-deposited, bedded tuffs. The low cliffs

1. An account of this discovery has not yet been published. The implement is in the possession of the National Museum, Melbourne.
2. Spencer and Walcott, "The Origin of Cuts on Bones of Australian Extinct Marsupials." Proc. Roy. Soc. Vict., pt. I., 1911, pp. 92-123.
3. The Geography of Victoria, Melb., 1903, p. 192, and revised edition, 1912, p. 204.

around Lake Terang, and a bank on the road leading to Gnotuk Park, near Camperdown, show the bedding, which indicates that the materials were laid down under water." If Professor Gregory's assertion be correct, that the tuff of the plains between Terang and Noorat, where the Pejark Marsh is situated, has been re-deposited, then the underlying clay bed may be younger, and not older than the volcanic rocks of the neighbourhood. This is a point of very considerable moment concerning the age of the human relic found in the clay bed, under the tuff.

In regard to the bedding of volcanic tuff, a common enough character in South-East Australia, Dr. T. S. Hall,[4] and Messrs. Mahony and Grayson[5] have shown, that it is by no means proof that the tuffs were laid down under water. On the contrary, the evidence indicates that they were mostly laid down on dry land, the exceptions being in those cases, such as at Pejark, where they may have been deposited in swamps or shallow lagoons.[6]

The direct deposition in these shallow and stagnant waters does not in any way affect the age of the tuffs; that question only arises where there is good and sufficient reason to believe that the tuffs have been, by the natural agency of wind or water, removed from their original places of deposition to others at a perhaps much later period.

The few facts gathered with regard to the Pejark tuff certainly seems to negative the idea that there has been any re-disposition of the material, and one of them is found in the numerous cavities it contains; a somewhat unusual feature in a rock of its character.

These cavities are of varying size and form, some being extremely regular, more especially the smaller ones, which are also generally spherical, but others again most irregular in shape. An examination in situ shows that the cavities are not all due to one cause. Some, the larger and mostly irregular ones, have a brownish coloured lining, and are found only near the bottom of the bed with the leaf impressions. These are undoubtedly the

4. Proc. Roy. Soc. Vict. Vol. XX., pt. I., 1909, pp. 20, 21.
5. Mem. Geol. Surv. of Vict., No. 9, 1910, p. 13, Geology of the Camperdown and Mt. Elephant Districts.
6. A specimen of tuff from Pejark Marsh, examined by F. Chapman, is stated by him to "show carbonized and iron-stained impressions of vegetable stems. When wax squeezes of these were taken they were seen to be triangular in section, and under the microscope show a structure exactly matching that of the surface in the living Victorian Marsh-loving *Cyperus lucidus*. The tuff specimen referred to also show excellent cross bedding disposed at a high angle to the plant-stems, thus indicating the formation of this deposit from gentle showers of volcanic dust."

result of the decay, and removal of vegetable remains. Higher up in the bed, where there is no sign of those remains, the smaller and more regular cavities occur in horizontal zones, and these likely enough have arisen through air entangled in the showers of ashes being carried with them to the bottom of the swamp, and there unable to escape.

In neither kind of cavity is there the slightest indication that it was formed by the gases given off by the decomposition of vegetation in the swamp in which the ashes fell. The presence of cavities due to air or other gases entangled in the shower of ashes, if it be a correct interpretation of the phenomenon, in itself sets at rest any doubts about the tuff not being in its original site, because such cavities could not have been retained during a re-distribution either by wind or water.

Mahony and Grayson,[7] in describing the microscopic characters of the Hampden tuffs, mention that a deposit at Blind Creek, about which some uncertainty exists as to whether it has been re-deposited or not, is similar to the tuffs occuring elsewhere in their original position. The same may be said of the Pejark tuff, as its character does not seem to differ from that of the beds of fine texture undoubtedly in situ. The Pejark bed is also sharply defined from both the underlying and overlying deposits, and there has been no mingling with extraneous material in any part of it. There are, then, no features in connection with the occurrence which might be held to indicate that it was laid down under conditions inconsistent with primary deposition.

The facts as they are, point not only to a sudden change in the nature of the deposited material, but to great rapidity of deposition with slight intervals of rest, during which the fine sediment suspended in the water of the lagoon or swamp settled, forming thin, impalpable seams in the tuff.

The whole bed was no doubt laid down in a comparatively short time, then earlier conditions again prevailed, and the present alluvial soil was deposited.

Regarding the origin of the tuff in question, there are three possible sources within the immediate neighbourhood of the place where the excavations were made, viz., Mt. Noorat, three miles to the north, Lake Keilambete, about two miles to the west, and Lake Terang, one mile due south.

The first of these sources and the most distant from the position mentioned, while leaving no question of its crater origin, has not

7. Loc. supra cit., p. 19.

yet supplied evidence of a sufficiently definite nature to prove that the tuff emanated from it. Mahony and Grayson[8] say that tuff was proved in wells sunk through the basalt to the north of the Mount, and they verbaly informed the writer that there was also evidence of tuff underlying the lavas in other directions.

This merely introduces the possibility of Mount Noorat having contributed to the Pejark tuff, but one of the other suggested places of origin is accompanied by evidence quite sound enough to fix it as the main source.

Lakes Keilambete and Terang, although surrounded by accumulations of tuff, have not been generally accepted as the sites of old volcanic vents.

Mr. A. R. C. Selwyn[9] thought they were more probably accidental depressions due to other causes, and Professor J. W. Gregory[10] is confident that they, as well as Lakes Bullemerri and Gnotuk, are not crater lakes, but occupy basins formed by subsidences in bedded volcanic tuff, which were probably caused by the eruptions of neighbouring volcanoes.

Mahony and Grayson,[11] on the other hand, hold that all these lakes are directly due to volcanic explosions, and with this view the writer is in accord. Their paper is a most valuable one, not only on account of the interesting matter it contains, but also because it is the only systematic account of the geology of the district yet published. As these notes must necessarily be brief, and only of a general nature, reference should be made to that paper.

The part of Lake Keilambete visited by the writer, like nearly the whole of its banks, was hidden by a luxurious growth of grass, with the exception of some outcrops of soft, tertiary, fossiliferous limestone underlying the superficial tuffs.[12]

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8. Loc. supra cit., p. 6.
9. Intercolonial Exhibition Essays, Melb., 1866.
10. The Geography of Victoria, Melb., 1903, p. 130. Revised Ed., 1913, pp. 131-136.
11. Loc. supra cit., p. 13.
12. Mr. F. Chapman, Palæontologist to the National Museum, who was good enough to examine all the fossiliferous material collected, determined the Lake Keilambete forms from the limestone as follows:—

    Foramnifera.—*Truncatulina lobatula*, W. and J. sp. Also others Indet.
    Polyzoa.—Indet.
    Echinidermata.—*Echinocyamus* (*Scutellina*) *patella*, Tate sp, Eupatagus (?) laubel, Duncan.
    Brachiopoda.—*Magellania insolita*, Tate sp., and *M.* (?) *pectoralis* Tate sp.
    Pelecypoda.—*Pecten yahliensis*, Tate.
    Pisces.—*Lamna apiculata*, Ag. sp.

    Mr. Chapman places the limestone bed in the Janjukian series.

Oyster shells of fossilized appearance occur on the beach of the lake, and it may be useful to record the fact here given to the writer by Mr. H. Quiney, of Mortlake, that many years ago an attempt was made to acclimatize oysters in the lake, but without success. It is to this source that the presence of the shells may be attributed.

The lake has an area of two square miles,[13] and is situated about two and a-half miles north-west of the township of Terang. Its circular form and low banks of volcanic tuff gently sloping into the surrounding plains on all sides, are very suggestive of volcanic origin. The fact that the banks are raised at all, unless they are of aeolian origin, makes it difficult to understand how they could have been formed if the lake is occupying a depression resulting from the withdrawal of material from below through the activity of neighbouring volcanoes.

It seems more reasonable to expect a gradual slope towards the lake by a sagging of the strata, instead of the reverse. Again, the symmetrical shape, which has been assumed, in place of one more or less irregular, as in the case of lakes situated in areas where the evidence supports an origin by subsidence, is more consistent with a volcanic origin. There is no evidence that this lake basin was formed in a depression in volcanic tuff. The tuff appears to have been deposited on a comparatively level land surface, through which the volcanic forces burst an opening. Mahony and Grayson[14] point out with regard to Lake Bullenmerri, which has only an area of a little over two square miles, is bounded by steep sides, and has its floor lying 700 feet below the highest part of the rim, that the formation of such a basin by the sinking of its floor has never been actually observed, but that there are instances of the production of similar depressions by paroxysmal explosions.

If it can be proved that the accumulations of tuff round the lake in situ thinned out as they receded from the lake itself, a strong piece of evidence would be established in favour of the basin being an explosion vent.

With regard to this, and several other points, Mr. A. J. Merry very kindly went to considerable trouble to ascertain what data were known from well sinkings in the neighbourhood. The result of his inquiries went to show that the well sinkings near Lake Keilambete all indicated a gradual reduction in the thickness of the tuff away from the lake, thus supplying the important evidence required. It is not certain, however, if this tuff extends to, and is continuous with, the Pejark bed. On the geological quarter sheet, buckshot gravel is seen to be the superficial deposit intervening between the former and the Pejark Marsh, and the nature of the underlying beds is not disclosed.

13. Intercolonial Exhibition Essays, Melbourne, 1866.
14. Loc. supra cit., p. 13.

While there may be certain characteristics absent from the formation of Lake Keilambete, they do not put nearly such a barrier in the way of ascribing its origin wholly, or in part to a volcanic explosion, as the presence of other characteristics do to the acceptance of the explanation that the lake basin is a simple subsidence in the land surface.

The site of Lake Keilambete may, therefore, be considered on good grounds the source from which the tuffs surounding it were derived, but evidence has not yet been collected to show that it has contributed to the Pejark Marsh tuff, although quite likely enough it has done so to some extent. Lake Terang has an area of one square mile,[15] or half that of Lake Keilambete, and, strangely enough, although it is without an apparent outlet, the water in it is fresh, unlike that of Keilambete. It also lacks the conspicuous circular form of Keilambete, and its irregularity, which is really not by any means marked, is emphasised by the varying height of the surrounding hills. The township of Terang is situated along the northern slope of these hills, but also spreads on to the level country, both eastward and northrward. At the east end of the lake the hills are low, forming a gradual rise from the country beyond. Following along the township the elevation increases right to the west end of the lake, where the greatest prominence is attained, and is deemed worthy of the title of Mount Terang. From Mt. Terang, tapering hills extend further to the westward. Continuing round the lake the land rapidly falls away until a gap, forming the lowest part of the ring, is reached, and this is succeeded again on the south by somewhat prominent hills extending to another gap at the east end.

The greatest depth of water, which is in the centre of the lake, at the time of the Author's visit (1909) was said to be three feet, In this respect it differs much from Lake Keilambete, which, according to the geological quarter sheet, had a depth of 96 feet in the year 1888. It is also said that when the early settlers came to Terang there were 30 feet or more of water in Lake Terang, and that it even flowed out through the gap on the south-west side. As the surface of the water has not been lowered to this extent, it is believed by local residents that the bottom has risen.

The growth of peaty vegetation has given some foundation for this belief, but it does not explain the reduction in the volume of water. This can only be accounted for by its draining away along

15. Intercolonial Exhibition Essays, Melbourne, 1866.

some subterranean passage. As already mentioned the water is fresh, and it would require a considerable access to bring the level up to the gap, which is said to have been reached in the past. There is no doubt that there has been a large diminution in the quantity of water in the lake within recent years, and if this is caused by the supply, either superficial, or superficial and subterranean combined, as the case may be, being exceeded by the loss due to evaporation, it would be noticed in the salinity of the water. Keilambete has also been lowered in level to some extent during the same time, but the saltness of its waters is very marked.

A suggestion might here be made with regard to this difference in the water of the two lakes which in other respects seem to have much in common. It has been mentioned that in another paper[16] that at Pejark Marsh, in driving a crowbar through the yellow clay, on the top of which cut fragments of bone were found, the bar entered a softer stratum, and water flowed freely from the hole so made, showing that probably the water-bearing bed from which the local residents obtain their supplies, had been tapped. It is also thought that this might be the porous fossiliferous limestone of Tertiary age exposed along the shores of Lake Keilambete for some feet above the present water level.

On the shores of this lake wells have been sunk for some twenty or thirty feet in the limestone, it is said, and fresh water obtained, although the lake water itself is so saline from the absence of an outlet that it is unfit for consumption by stock. It, therefore, seems evident that the limestone bed is a channel by which the supply of water to Keilambete is augmented to some extent. Now at Lake Terang conditions are apparently different, and the process is reversed. In this case the water is either being forced out through the porous stratum into the surrounding country, where numerous wells are drawing it away more rapidly than before the stratum was tapped, and more rapidly than it can be naturally replenished, or else underground supplies, which were sufficient to balance the loss by subterranean outlets, have been intercepted. Mahony and Grayson[17] mention this as a probable factor in the desiccation going on at Lake Terang.

The sides of the lake, or ring of hills enclosing it, are composed principally of bedded tuffs. An extremely good exposure occurs

16. Spencer and Walcott, "The Origin of Cuts on Bones of Australian Extinct Marsupials." Proc. Roy. Soc. Vict., Pt. I., 1911, p. 93.
17. Loc. supra cit., p. 10.

just at the back of the Mechanics' Institute, where they have been quarried for building stone, and a clean vertical fcac about ten feet in height has been left. The beds here are of much coarser texture than at Pejark Marsh, and scattered through them are small lumps of white, indurated clay, which impart the effect produced by splashes of whitewash. An interesting feature was noticed here near the top of the beds, giving evidence that a volcanic vent was not far distant. This was the characteristic bend in the bedding of the tuff caused by impact of a falling body, and occurred under a cavity at one time occupied by a bomb or ejected block.

At Mt. Terang, where the tuff is being quarried just to the north of the summit, the beds are seen to be dipping, as far as can be made out, with the outward and northward slope of the hill. They are capped by a thin flow of scoriaceous basalt, which seems to form the cover of the hills extending to the west. Clay enclosures are also noticed here, but not so abundantly, and in one place the lava has intruded the tuff in the form of a small dyke now largely decomposed.

Just south of the summit of Mt. Terang, where a cutting for a road has been made, from what can be seen, the beds generally show a dip towards the lake, but as they have here been disturbed and become almost vertical within a short distance, where they abut on a coarse agglomerate or mass of volcanic ejectamenta, it is not quite certain whether this is the true direction of dip or not. It may be that this agglomerate is occupying a vent, and that the disturbance and rapid change in dip of the bedded tuffs has been caused by the downward drag of the volcanic material during its settlement. Enclosed in the agglomerate are lumps of flesh-coloured clay, reaching up to the size of a man's head. They are indurated by the heat to which they have been subjected, and mostly exhibit an imperfect prismatic structure from the same cause. These enclosures are of considerable interest on account of the fossils some of them contain, bearing witness of the presence of the marine tertiary beds underlying the volcanic deposits of the district, and from which they have been derived. Mr. F. Chapman identified these fossils as belonging to two Polyzoan genera—*Adeona* and *Lepralia*, and a brachiopod, doubtfully referred to the genus *Crania*. If, then, we have here no evidence that the site of an old vent lies within the limits of Lake Terang, from whence came the various materials forming the mount and the surround-

ing hills? The ejected lumps of the older underlying rocks alone testify to the presence of a not distant source. On the eastward outward slope of the lake near the cemetery, a well put down passed through about 80 feet of tuff before striking water, but half a mile or so further east, poor "buckshot" country is encountered resting on, it is said, a clay bed. Again, near the summit of Mount Terang, another well was sunk, and a still greater thickness of tuff was met with. Mr. Merry also says that to the west and south of the lake the good volcanic country is succeeded by "buckshot" and clay lands. The geological quarter sheet shows what is called the "older volcanic series," giving place to "buckshot" gravel to the west, but to the north extending to the limits of the quarter sheet. The title given to this series is badly chosen, and misleading, as it does not refer to the older basalts, known as such since the time of the first geological survey of Victoria, but to a section of the newer volcanic rocks belonging to a much more recent period. Apart from the confusion occasioned thereby, "older" is an inappropriate term to employ, as the basalt it is applied to, is in part superficial, and at Lake Terang mapped right up to its side, so that it must be younger than the tuffs there, and Mahony and Grayson state that the basalts belong to one cycle of activity, no sharp line of demarcation separating them. These authors[18] have very properly in their paper substituted the terms "earlier" and "later" for the older and newer volcanic series of the quarter sheet. To the north of Lake Terang we know that at the Pejark drain, distant about a mile, there is at the most only two feet of tuff, and Mr. Merry ascertained that between the drain and the lake the tuff or "sandstone" had been encountered in every well sinking and cellar excavation, increasing in thickness as the lake was approached. The actual thickness of the tuff bed on that side of the lake could not be found out. The section behind the Mechanics' Institute shows a face of 10 feet. This establishes the continuity of the Pejark and Lake Terang tuffs, and makes it probable enough that they originated from the same point, although of course, as already stated, they may have blended to some extent to the west and north with the tuffs which emanated from the site of Lake Keilambete and from Mt. Noorat.

As the tuffs of Lake Terang are unquestionably occupying their original place of deposition, and are continuous with, and thin out into, the Pejark beds, there seems no reason to attribute the

18. Loc. supra cit., p. 4.

occurrence of the latter to re-deposition. If Lake Terang does not represent an ancient centre of volcanic activity, it is inconceivable how a mass of volcanic ashes and coarser ejectamenta, covered with lava for the greater part, and undoubtedly in situ, came to be piled up there where there is no evidence whatever to connect its presence with any other possible source of origin.

It is possible, however, that the crater basin ocupied by the lake may have been enlarged by subsidence through the withdrawal of material from below.

In view of the facts given it may fairly safely be taken that any works of man discovered beneath the tuffs of the areas under consideration would at least put his history back to the last great epoch of volcanic activity in south-west Victoria, and make him the contemporary of our giant extinct marsupial fauna.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. II.—*New or Little-known Victorian Fossils in the National Museum.*

Part XXIV.—On a Fossil Tortoise in Ironstone from Carapook, near Casterton.

By FREDERICK CHAPMAN, A.L.S.
(Palæontologist, National Museum, Melbourne.)

(With Plate I).

[Read 8th May, 1919].

Note on the Matrix.

Bog iron-ore, known mineralogically as a form of Limonite ($2Fe_2O_3 + 3H_2O$), is a common preservative of fossil plants and animals, in which their remains are usually found as casts and impressions. In Victoria we have numerous instances of such occurrences of beds of ironstone; as for example, the deposit on the Parwan Creek, and other exposures near Bacchus Marsh, which contain leaves of Laurel, Cinnamon and Beech.

Of terrestrial or freshwater (lacustrine) origin, these bog iron-ores contain the remains either of the organisms which were living in the swamps and lakes, as the ostracoda and shells; or remains of animals as bones and feathers, which were washed into the deposit off the land.

In the case of the Swedish lake iron-ores, the higher bacteria have played a prominent part in separating the iron oxide from the water, and such may have been the case with the beds of iron-stone near Casterton in which the above fossil tortoise was found. The iron was in all probability derived from the vast outpourings of lava during late Tertiary times in Victoria, being dissolved out by meteoric waters and re-deposited in pans on the bottoms of swamps and lakes.

Description of Specimen.

The practically unique fossil now under consideration was found in a bed of ironstone at Carapook, north-east of Casterton. It represents a replacement in limonite of the greater part of the body cavity of a tortoise. On the dorsal surface the vertebral

column is well-marked by a deep, interrupted groove. The sutures of the costal plates are faintly visible. The impressions of the bones of the pelvic girdle are also seen. On the ventral side impressions of the bones of the plastron may be made out, and also those of the epidermal plates; of the latter the most strongly marked are the grooves between the pectoral and abdominal shields.

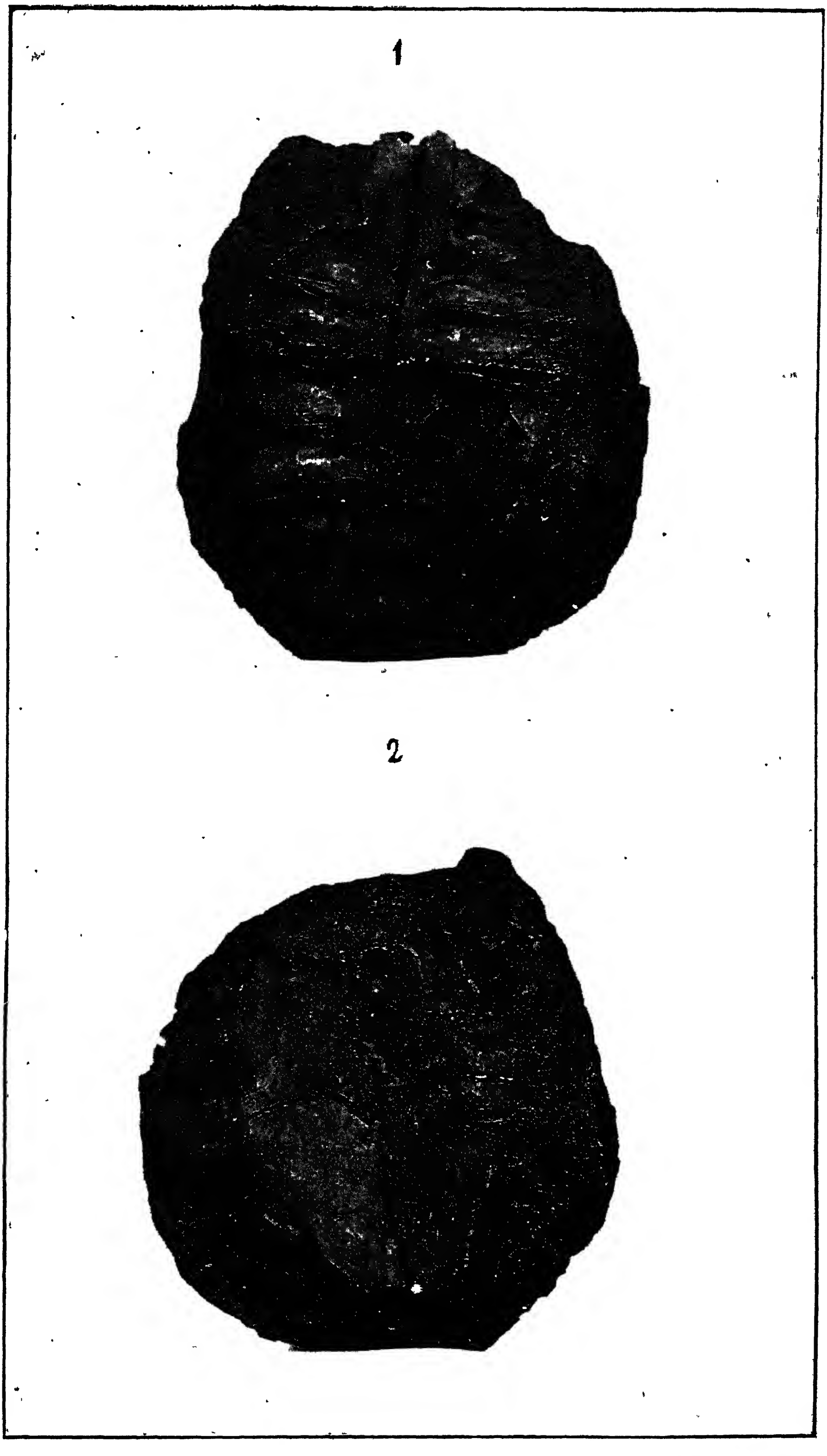
This fossil cast is referable to the genus *Emydura*, Bonaparte,[1] to which the Murray Mud-tortoise belongs. From all appearances the fossil may be referred, with some reservation, to the same species, *Emydura macquariae*, Gray sp.[2]

The length of the fossil specimen when complete was about 28 cm., as against 27 cm. of a full-grown living specimen.[3] Breadth, about 15 cm. A living example from Wahgunyah, mentioned by McCoy, shows almost identical proportions. This fossil is slightly broader in proportion, both across the carapace and plastron, than the living specimens, but this difference seems to be due to compression.

Observations.—The Murray Mud-tortoise is common in the River Murray and its tributaries and branches, but is not found in Victoria in rivers flowing to the south. This curious point in its local distribution may indicate the once northern trend of the rivers in the Casterton district, which now join the Glenelg.

Anent the discovery of the specimen, the question arises whether this ironstone deposit bears any relationship to that occurring at Redruth, which yielded *Eucalyptus* and *Banksia* leaves, and a bird's feather.[4] Carapook is in the same district as Redruth, and

1. Arch. f. Naturgeschichte, 1838, Vol. I., p. 140.
2. *Hydraspis macquarii*, Gray, 1831, Syd. Rept., p. 40.
   Platemys macquariae, Gray sp., Dumeril and Bibron, Erp. Gen., Vol. II., p. 438.
   Hydraspis victoriae, Gray 1842, Zool. Misc., p. 55.
   Chelymys macquaria (pars), Gray, 1844, Cat. Tort, p. 42 .
   Euchelymys sulcifera, Gray, 1871. Ann. Mag. Nat. Hist. ser. 4, Vol. VIII., p. 118.
   Euchelymys sulcifera, Gray, 1872, Proc. Zool. Soc. Lond., p. 508.
   Chelymys victoriae (pars), Gray, Proc. Zool. Soc. Lond., p. 506, pl. XXVII.
   Chelymys macquaria, Cuvier sp. McCoy, 1884, Prod. Zool. Vict. pp. 11-14, pl LXXXII. and LXXXIII.
   Emydura macquariae, Gray sp. Boulenger, 1889, Cat. Chelonians, Rhynchocephalians and Crocodiles in the Brit. Mus., p. 230, Fig. 63.
   Emydura macquariae, Lydekker, 1889, Cat. Foss. Rept. and Amphibia. Brit. Mus., p. 169.
3. Prod. Zool. Vict., Vol. I., 1884, p. 12.
4. See Proc. Roy. Soc. Vict., Vol. XXIII. (N.S.), pt. I., 1910, pp. 23-26, pls. IV., V.



F.C. photo. circ. ½ nat. size.

Fossil Cast of Emydura, cf. Macquarie, Gray sp., Carapook.

lies 20 miles to the N.W. The probable age of the Redruth ironstone was, in my original description, put down as Miocene, but it is possible that it may be of later age. This can only be proved in conjunction with more precise field evidence than we have at present.

Occurrence.—In an ironstone bed, three feet from the surface, at Carapook, N.W. of Casterton. Presented by Mr. James S. Macpherson.

Age.—Probably Pleistocene.

Previous records of Fossil remains of EMYDURA MACQUARIAE.—R. Lydekker has recorded[5] two fragmentary specimens of the above species from the collection at the British Museum (Natural History), London. One of these is "An imperfect eighth marginal bone of the right side, belonging either to this or an allied species." Its locality is doubtful, but "apparently from the Pleistocene cave-deposits of New South Wales.

The other is "An imperfect right tenth marginal, probably referable to the same species as the preceding; from the Pleistocene cave-deposits of the Wellington Valley, New South Wales. This specimen appears to include part of the eighth costal."

EXPLANATION OF PLATE I.

Fig. 1.—*Emydura* cf. *macquariae*, Gray sp. Dorsal surface of cast in ironstone. Carapook, near Casterton. About half natural size.

Fig. 2—Lower surface of the same specimen. About half natural size.

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5 Cat. Foss. Reptilia and Amphibia in the British Museum (Nat. Hist.), pt. III., 1889, p. 169.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. I., 1919].

ART. III.—*On the Essential Oil of Boronia pinnata, Sm. and the presence of Elemicin.*

BY HENRY G. SMITH, F.C.S.
(Sydney Technological Museum).

[Read 10th July, 1919].

The Boronias (N. O. Rutaceae) are plentifully distributed in Australia, and constitute a genus the flowers of which are often strongly perfumed.

The essential oil, the subject of this communication, was distilled by Mr. P. R. H. St. John, in Melbourne, from material collected, towards the end of the year 1917, in the Longwarry District of Victoria. The plant at that time of the year was in full bloom.

Very few species of Boronia have so far been worked for their oil, and consequently little is at present known concerning the constitution of their odoriferous products.

In this case it is particularly interesting to know that almost three-fourths of the oil consists of the trimethoxy-phenol ether, Elemicin.

This substance which is 4-allyl—1,2,6, trimethoxy-benzol; $C_{12}H_{16}O_3$, occurs in the higher boiling portion of the oil of Manila Elemi, and it was from this oil that it was first isolated, and its characters and composition determined.

The constants given for Elemicin are:—boiling point 144-147°C. at 10 millimetres pressure; density at 20° = 1.063, refractive index 1.5284; also that it occurs in the fraction of the oil boiling at 277-280°C.

The oil of *Manila Elemi*, distilled from the oleo-resin of *Canarium commune*, L., is thus derived from plants belonging to the Burseraceæ, a natural order somewhat far removed, systematically, from the Rutaceæ, to which Boronia belongs, and it is thus interesting to find this rare plant constituent so widely distributed.

The slight fluorescence of the oil is also worthy of remark, because it seems very probable that this was wholly or partly due to the presence of a small quantity of the methyl-ester of anthranilic acid, which constituent it was possible to extract from the oil by agitating with dilute sulphuric acid. As the plant was in flower at the time of distillation, it is probable that this ester

was derived from the flowers, and it may be found not to occur in the leaves. Although the fluorescence of the oil was apparently considerably diminished after agitation with dilute acid, yet it was not entirely removed in this way.

A considerable amount of work has been carried out on elemicin, and iso-elemicin, by Semmler (Ber. 1908, 41, 1768, and other references in the same volume), the material worked upon having been derived from Elemi oil.

This is the first time elemicin has been detected in the oils of Australian plants.

My thanks are due to Mr. F. W. Byrne, of the Chemical Department of the Museum, for assistance in this investigation.

Experimental.

The total yield of oil was equal to 0.383 per cent. The crude oil, which was heavier than water, was of a light amber colour, and had a mild aromatic odour, suggesting the presence of geraniol and geranyl-acetate. It also had a slight fluorescence. When dissolved in absolute alcohol the secondary odour was pleasant, and it appears that the oil of this species of Boronia will be found a useful addition to the perfumery products of Australia.

The crude oil had :—

Specific gravity at 15°C. = 1.0197.
Rotation $^{a}D = +3.8°$.
Refractive index at 20°C = 1.5125.
Soluble in 1 vol. 70 per cent. alcohol (by weight).

The dextrorotation of the oil was due to the activity of a small quantity of pinene; this is shown later.

The saponification number for the esters was determined both by boiling and in the cold.

(a) 1.5252 grams boiled for half-an-hour with alcoholic potash, required 0.0308 gram KOH. S.N. = 20.2.

(b) 1.528 grams treated with alcoholic potash in the cold with two hours' contact required 0.028 gram KOH. S.N. = 18.3.

This result is important, and, together with the odour, indicates that the chief ester in the oil is geranyl-acetate, and that it occurs to the extent of 6.4 per cent.

That free geraniol was also present is suggested from the results of acetylation. A portion of the crude oil was boiled with acetic anhydride and anhydrous sodium acetate in the usual way.

(a) 1.5144 grams of this esterised oil, when boiled with alcoholic potash, required 0.056 gram KOH. S.N. = 36.9.

(b) 1.5162 grams, when treated with alcoholic potash in the cold, with two hours' contact, required, 0.042 gram KOH. S.N. = 27.7.

To confirm this result some cold saponified oil was steam distilled. Besides the terpenes an aromatic alcohol came over, which was strongly indicative of geraniol.

Although the chief alcohol may be considered to be geraniol, yet it is evident that other alcohols were also present.

Determination of Combined Acids.

A portion of the crude oil was boiled for two hours with an aqueous solution of sodium hydroxide. The alkaline solution was separated and acidified with sulphuric acid. The clear filtered solution was distilled until volatile acids ceased to come over. The distillate was neutralised with Barium hydrate solution, evaporated to dryness and treated in the ordinary way.

(a) 0.1868 gram Barium salt gave 0.1580 gram $BaSO_4$ = 84.58 per cent.

(b) 0.2306 gram Barium salt gave 0.1958 gram $BaSO_4$ = 84.91 per cent.

On treating the Barium salt with sulphuric acid the odour of butyric acid was noticeable; it is thus assumed that butyric acid was also present. The results obtained are equal to 59.8 per cent. of Barium acetate, and 40.2 per cent. Barium butyrate. The acetic acid was evidently in combination with the geraniol as geranyl-acetate.

The amount of free acid in the crude oil could not be satisfactorily determined for several reasons, and although a small amount of a solid acid was eventually isolated, yet the saponification number was under 2.

Phenol and Free Solid Acid.

A portion of the oil was shaken with dilute sodium hydroxide until extraction was complete. The aqueous solution was separated, shaken with ether to remove adhering oil, acidified, and again shaken with ether. The ether extract thus obtained was equal to 0.198 per cent., and was semi-crystalline, due to the presence of the solid acid.

The product was dark coloured, and had a strong phenolic odour. It was dissolved in ether, and the acid removed from the phenol by shaking with a solution of Sodium carbonate. The small quantity of acid when finally purified, was crystalline, and melted at 159-160°C. It was not cinnamic acid, and perhaps consisted of trimethylgallic acid, which is formed by oxidation of elemicin.

The ether solution of the phenol after removal of the acid was evaporated to dryness. The residue had a strong phenolic or creosote-like odour, was not crystalline, and when dissolved in alcohol gave a purplish-brown colour with ferric chloride, which colour remained persistent.

Tests for some of the well-known phenols gave negative results, and as the amount was small, its identity could not be determined.

The oil, after the removal of the phenol and free acid, was repeatedly shaken for some days, with a saturated solution of sodium bisulphite, but no combination took place. Aldehydes were thus absent.

Distillation of the Crude Oil.

100 c.c of the crude oil were submitted to distillation under atmospheric pressure. A few drops of an acid water with a little oil came over below 160°C. (uncorrected). Between 160-250° only 16.5 c.c. came over as first fraction, 10 c.c. of which distilled below 180°.

Thes temperature rose rapidly to 259°, and distillation then proceeded as follows:—

259-265° = 18 c.c.
265-270° = 50 c.c.
270-274° = 63 c.c.
274-280° = 70 c.c.

This fraction was then separated, and although 3 c.c. of an oil came over on continued heating, yet the temperature did not rise beyond 280°. The residue in the still was a dark hard pitch-like substance, which powdered readily when cold.

The first fraction gave the following results:—

Specific gravity at 15°C. = 0.8657.
Rotation $\alpha_D = +15.9°$.
Refractive index at 20° = 1.4639.

Cineol was not present. The oil of this fraction was fluorescent.

15 c.c. of the first fraction were again distilled, when 7.5 c.c. came over below 158°C., and 5.5 c.c. between 158-190°. The

portion distilling below 158° had

Specific gravity at 15° = 0.8596.

Rotation $^{a}D = +21.2°$.

Refractive index at 20° = 1.4569.

and formed a nitrosochloride, which melted at 104°C.

The lower boiling constituent in the oil was thus shown to be dextrorotatory pinene.

Possibly limonene was also present in the intermediate portion, as the specific gravity was only 0.8590.

The second, or large fraction, gave the following results:—

Specific gravity at 15°C. = 1.0519.

Rotation $^{a}D = +0.4°$.

Refractive index, at 20° = 1.5230.

Soluble in 0.5 volume of 70 per cent. alcohol, remaining clear on further addition.

After removal of any phenol which might be present in this fraction, it was again distilled under reduced pressure, the first 15 c.c. being discarded. The remainder boiled fairly constant at 191°C. under 47 millimetres pressure. The product gave the following results:—

Specific gravity at 20°C. = 1.0705.

Inactive to polarised light.

Refractive index at 24°C = 1.5283.

It was thus considered that the bulk of the oil consisted of this constituent. When freshly distilled, it was practically colourless, had a slight fluorescence, and a delicate aromatic odour, reminding somewhat of linalool. It darkened slightly on keeping.

Analysis gave the following;—

(a) 0.1688 gram gave 0.1196 H_2O; and 0.4222 CO_2 : H = 7.87 and C. 68.22 per cent.

(b) 0.1332 gram gave 0.0932 H_2O; and 0.3362 CO_2 : H = 7.8 and C. 68.85 per cent.

$C_{12}H_{16}O_3$ requires H. 7.75 and C. 69.1.

Methoxy Determination.

(a) 0.2872 gram gave 0.9498 AgI equal to 43.6% OCH_3.

(b) 0.3144 gram gave 0.9939 AgI equal to 41.8% OCH_3.

It is thus evident that the molecule $C_{12}H_{16}O_3$ contains three methoxy groups.

That the molecule was unsaturated was shown by the action of Bromine, when the substance was dissolved in carbon tetrachloride,

although a satisfactory bromide was not obtained. At first the bromine was absorbed without evolution of hydrobromic acid, but later the evolution of HBr. was pronounced, the solution becoming dark purple.

Formation of the Acid.

A portion was oxidised by Potassium permanganate in alkaline solution; considerable heat was evolved. After completion of the reaction, the remaining colour was removed by sulphurous acid, filtered, evaporated to small bulk, and acidified with dilute sulphuric acid. A solid acid separated at once. This was purified from boiling water, from which it crystallised in needles. It melted sharply at 169°C (corr.) without decomposition. The acid was titrated with decinormal sodium hydroxide; 0.13 gram dissolved in absolute alcohol required 6.15 c.c. $\frac{1}{10}$ NaOH to neutralise, thus 40 grams would neutralise 211.4 grams of acid, $C_{10}H_{12}O_5 = 212$.

It was thus evident that the acid was trimethylgallic acid $C_{10}H_{12}O_5$, the characteristic acid formed by the oxidation of elemicin.

That a small quantity of iso-elemicin was also present was indicated by the formation of a minute quantity of acetic acid on oxidation by Potassium permanganate. This was shown by distilling over the free acid and forming with it the Barium salt. This on ignition gave 91.6 per cent. $BaSO_4$. Theory requires 91.37 per cent.

The above investigation shows that the principal constituent in the oil of *Boronia pinnata* is the trimethoxyphenol-ether, Elemicin, (4 allyl—1,2,6 trimethoxybenzol) and that it occurs in the oil of this species to the extent of about 70 per cent.

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[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. IV.—*On the "Clawing" Action of Rain in Sub-Arid Western Australia.*

By J. T. JUTSON

(With Plate II.).

[Read 10th July, 1919].

Introduction.

In sub-arid south-central Western Australia, which is portion of the great plateau of that country, erosion presents results different in many ways from those obtained in areas possessing a "normal" climate. This is partly due to the difference in degree, and to some extent in kind, of the erosional agents, and partly to the surface alteration that rocks and soils have in many parts sustained. There are certain minor features which are peculiar to the area, and therefore of interest. Such are the miniature soil-terraces described in this paper, the formation of which is associated with the "clawing" action of rain, and with the gravitational drift of rock debris.

Summary.

The "clawing" action of rain on gentle soil-covered slopes with a firm surface produces terraces with tiny cliffs, which are termed "miniature soil-terraces," and at the same time gradually removes the soil to lower ground. By the formation and recession of these terraces, drifting rock debris is undermined, and topples forward down the slopes. Thus a decided aid is given to the slow, gravitational drift of rock debris from higher to lower parts.

Description of the Processes.

In sub-arid south-central Western Australia there is a widespread tendency to form hard caps at the surface, owing to water being drawn there by capillary attraction, and to evaporation then taking place with deposition of the contained salts.

Soils are no exception to this process, although the cap is in places but a mere film of slightly firmer material than that below. This film, however, is quite sufficient to influence the transporting action of the rain. On many gentle soil-covered slopes, especially

those covered by a sandy loam, the rain passes over the film in thin sheets or rills without furrowing the ground, despite the latter having many spaces bare of vegetation. Where the film becomes broken by any means, miniature waterfalls occur, due to the flow of water over the film to the softer soil beneath. Tiny cliffs are thus formed.

These tiny cliffs may be only from an inch to six inches in height, but they may extend laterally—that is, approximately at right angles to the direction of water-flow—for many yards, and thus form a miniature soil terrace on the slope. Other similar terraces may form above and below; and thus on a gentle slope several such terraces may be seen rising one above another, separated by varying distances, but usually fairly close together.

The actual outline of a terrace (see Plate II., Fig. 1) may be described as a series of gentle curves or scallops, mostly concave to the ground at the foot of the "cliffs," and each curve usually presents a minutely crenulated edge. This appearance suggests some force that has gently clawed away the soil, and hence the writer terms the rain action "clawing," Tiny furrows may run from the "clawed" edges, indicating the directions of the minute rills. These furrows usually tend to unite within a few feet from the edges into a larger one, but within a few more feet this larger furrow dies out, owing to the action of the water in depositing the transported fine sand and soil as a series of minute, flat alluvial fans or "lobes." The surface of the lower ground by reason of such deposit becomes levelled off, thus illustrating, on a very small scale, one result of rain action in this country. Another general result is the slow transportation by rain of soil from higher to lower ground.

Extensive areas of rock fragments slowly drifting from higher to lower ground form one of the commonest surface features in sub-arid south-central Western Australia; but only the most resistant rocks, such as quartz, jasper and ironstone, travel any distance. On the soil-covered terraces, such loose pieces of rock often occur; and, as "clawing" proceeds, these fragments are seen in course of being undermined. Eventually they topple over to the lower level, and by repetition of this process their migration down the slope is largely accomplished.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. I., 1919].

ART. V.—*A Striking Example of Rock Expansion by Temperature Variation in Sub-Arid Western Australia.*

BY J. T. JUTSON.

(With Plate II.).

[Read 10th July, 1919].

A rather remarkable example of rock expansion, due to temperature-variation, having come under the writer's notice in sub-arid Western Australia, its record may be of value. It occurs about ten miles to the north-north-west of Comet Vale, a mining township about sixty miles north of Kalgoorlie, on the Kalgoorlie-Laverton railway line. It is, therefore, situated well in the interior of Western Australia, in an area of low rainfall and of great temperature variations.

The rock is a biotite granite, which outcrops as a bare rounded hill rising to an inconsiderable height above the surrounding plain. This rock is, therefore, constantly exposed to the weather; and, owing to the great variations in daily and nightly temperature, it peels off in layers or bands of various thickness, with the result that the rock assumes the well-known rounded appearance characteristic of granite. This peeling or flaking off is the "desquamation" of Richthofen.[1]

The particular occurrence referred to is a surface slab of granite, on the lower slope of the hill, abutting a "gnamma," or natural rock-hole. This slab is 10 feet long, two feet six inches wide, and ranges from one and a half to four inches in thickness. It is separated from the parent mass, except at its ends (which here mean the terminations roughly at right angles to its length). These ends pass into rock of similar character, but the slab rises in a gentle curve towards the centre, where it is not resting on anything (except possibly at one point on a loose boulder that has drifted into the cavity). On the uphill and downhill sides of the slab, at the centres of the respective sides, the height of the lower face of the slab from the surface of the solid rock below is seven inches and four and a-half inches respectively. The slab is cracked

1. Hume, W. F., "Professor Walther's Erosion in the Desert Considered." Geol. Mag., Decade VI., Vol. I., Nos. 595-6 (1914), p. 21.

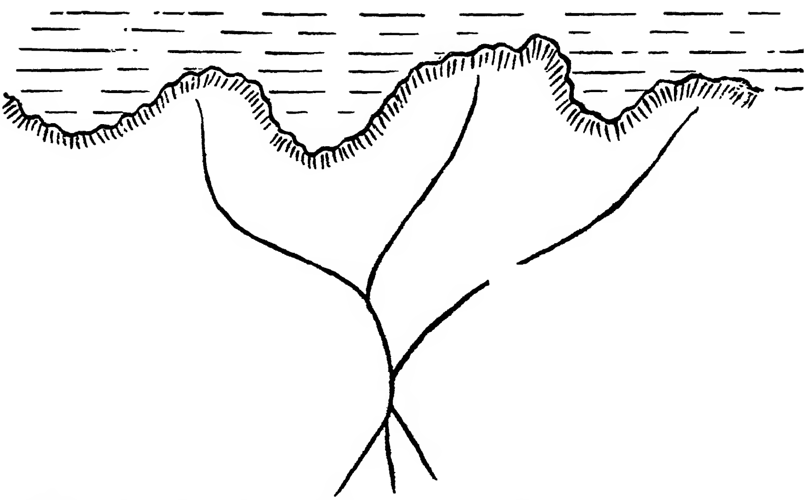

Fig. 1—The figure shows the tiny rain furrows running from the foot of the "cliffs," uniting, and then dying out as "distributaries."

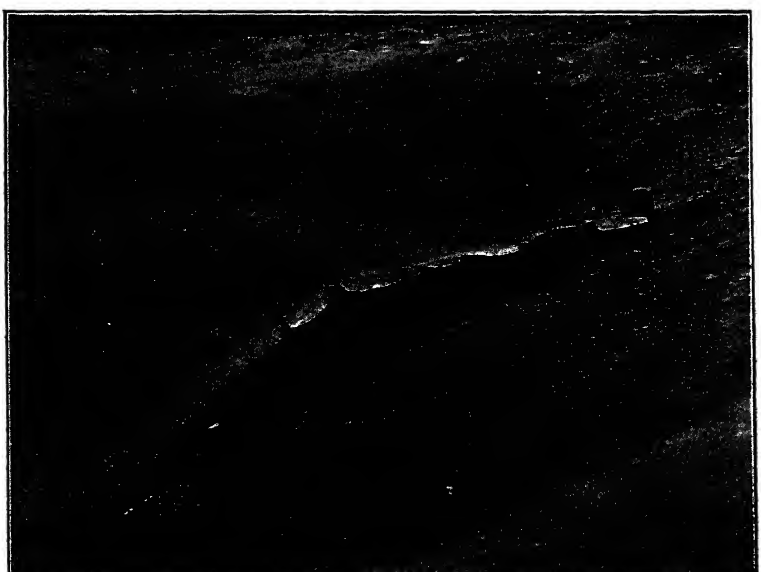

Fig. 2.

right through (vertically and horizontally) across the centre, and the portion on one side of the crack has sunk one half of an inch to an inch below the other portion.

This slab of rock has, therefore, been bent and raised to a maximum height of seven inches above the solid rock below; and its bending power was so great that it attained this height before breaking. Temperature variation appears to be the only cause of this phenomenon.

The accompanying photograph (Plate II., Fig. 2), illustrates the features here described.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. VI.—*On an Ostracod and Shell Marl of Pleistocene Age from Boneo Swamp, West of Cape Schanck, Victoria.*

By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

(With Plates III. and IV).

[Read 10th July, 1919].

Description of Deposit.

The dried marl is of a whitish-grey colour, but when wet is grey to smoke-brown. It is light in weight and cavernous in places, the holes being due to the roots and stems of plants, which have been enclosed in the deposit.

The molluscan shells are mainly of freshwater types, belonging to the genera *Bullinus* and *Coxiella*, but the marine genus, *Erycina*, is also well represented.

Ostracoda are chiefly of aquatic character, as *Cypris* and *Candonopsis; Limnicythere* is a genus which is usually found in streams and lakes, draining high land, and in close proximity to the sea; *Cythere* (*C. lubbockiana*), though rare in this deposit, is a true marine ostracod.

Under a high power of the microscope the fine washings are seen to consist of minute rounded particles mingled with fragments of ostracoda, and a few freshwater diatoms (*Cymbella*). This genus of diatomaceae has been previously recorded from several Victorian localities of Pleistocene age, in deposits of a freshwater or lacustrine nature, as those of Mickleham (det. by author), Eglinton, Amherst, Coralulup, Splitter's Creek, Rodborough, Belfast and Talbot.[1]

The material is almost purely calcareous. On testing it for phosphoric acid, no reaction was obtained.

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1. See Mahony, D. J. Bull, Geol. Surv. Vict., No. 26. 1912. pp. 12, 15 and 16.

Description of Fauna.

PHYLUM MOLLUSCA.

Class PELECYPODA.

Fam. LEPTONIDAE.

Genus ERYCINA, Lamarck.

Erycina helmsi, Hedley. (Plate III., Figs. 1, 2.)

Erycina helmsi, Hedley, 1915, Proc. Linn. Soc., N.S. Wales, vol. XXXIX., pt. IV., p. 701, pl. LXXX. Figs. 37-39. Chapman and Gabriel, 1917, Proc. R. Soc. Vict., vol. XXX. (N.S.), pt. I., p. 6.

Observations.—It is interesting to meet with this little bivalve in these sub-fossil deposits, in which the majority of forms are of freshwater habitat. The localities where it is found living are Dee Why Lagoon, New South Wales; and in Victoria, at Port Melbourne, Corio Bay, Altona Bay, Port Albert and Lakes Entrance. Mr. C. J. Gabriel and the author also recorded it (loc. supra cit.) from the Pleistocene deposits underlying volcanic tuff near Warrnambool, where it occurred abundantly in association with many marine shells and a few brackish water forms. Some specimens from Lake Connewarre, near Geelong, in the Dennant collection, labelled "*Pisidium etheridgei,*" also belong to the above species. At first glance, this small form might easily be mistaken for the aquatic genus, *Pisidium*, but an examination of the hinge-line is sufficient to show the difference.

Occurrence.—Common in the Boneo Swamp deposit.

Class GASTEROPODA.

Fam. TRUNCATELLIDAE.

Genus COXIELLA, E. A. Smith.

Coxiella striatula, Menke sp. (Plate III., Fig. 3.)

Truncatella striatula, Menke, 1842, Moll. Nov. Holl., p. 9.

Blanfordia pyrrhostoma, Cox, 1868, Mon. Austr. Land Shells, p. 95, pl. XV., Fig. 14.

Pomiatopsis striatula, Menke sp. Tenison Woods, 1876, Proc. Roy. Soc. Tas. for 1875, p. 78.

Coxiella striatula, Menke sp., E. A. Smith, 1898, Proc. Malac. Soc., vol. III. p. 75.

Coxiella confusa, E. A Smith, 1898, Ibid. p. 76.

Coxiella striatula, Menke sp., Hedley, 1916, Prelim. Index. Moll. W. Austr., p. 189.

Observations.—Some of the shells of this freshwater or brackish lacustrine species have as many as six whorls. The periostracum having been removed by natural decay, the ornament is clearly seen as a longitudinal striation with occasional stronger varicial striae, crossed by finer lineations. The young examples of about three whorls are not decollated, the protoconch showing as a smooth depressed spiral of about one and a-half whorls.

The cleaned surfaces of the shells point to a slight age for this deposit, although it should be borne in mind that the margins of some swamps where this species abounds are covered with layers of the shells in this condition.

C. striatula is a very widely distributed form in Australia.

Occurrence.—Common in the Boneo Swamp deposit.

Fam PLANORBIDAE.

Genus BULLINUS, Oken.

Bullinus acutispira, Tryon, sp. Plate III., Fig. 4.

Physa acutispira, Tryon, 1866, Amer. Journ. Conch. vol. II. p. 9, pl. II., Fig. 10. Tate and Brazier, 1881, Proc. Linn. Soc. N.S. Wales, vol. VI., p. 557. Smith, 1882, Journ. Linn. Soc. Lond. Zool., vol. XVI. p. 282; pl. VI., Fig. 16. Clessin, 1885, Conch. Cab., vol. I. pt. 17, p. 242, pl. XXXIV., Fig. 1.

Bullinus acutispira Tryon sp., Hedley, 1917, Rec. Austr. Mus., vol. XII., No. 1, p. 5, pl. I., Figs. 11-13.

Observations.—The present speciments of these freshwater shells from Boneo Swamp are of thicker build than the var. *yarraensis*, T. Woods,[2] and are therefore referred to the type species.

Bullinus tasmanicus, T. Woods sp.[3] closely resembles the above species, but the apex is not so acute, nor is the aperture so open. The species and variety have been recorded from Horsham, Cape Grant, near Portland, Yan Yean Reservoir, Bunyip River, and Carrum Creek, Frankston. One of the Boneo Swamp specimens has an elongated spire, and resembles the figured specimen of Hedley's, from Horsham.

Occurrence.—This specimen is fairly numerous in the Boneo Swamp material.

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2. *Physa yarraensis*, T. Woods, Proc. Roy. Soc. Vict. Vol. XIV., 1878, p. 64. *Bullinus acutispira*, Tryon, sp., var. *yarraensis* T. Woods var. Hedley, 1917, Rec. Austr. Mus., Vol. XII., No. 1, p. 5, pl. II., Fig. 16.

3. *Physa tasmanica*, T. Woods, Proc. R. Soc. Tasmania, for 1875 (176), p. 74. *Bullinus tasmanicus*, T. Woods, sp. Chapman, Mem. Nat. Mus., Melbourne, No. 5, 1914, p. 58, pl. I., Figs. 5, 5*a*.

Class CRUSTACEA.

Super-order OSTRACODA.

Fam. CYPRIDAE.

Genus CYPRIS, Müller.

Cypris mytiloides, G. S. Brady. (Plate III., Figs. 5, 5*a*.)

Cypris mytiloides, G. S. Brady, 1886, Proc. Zool Soc. Lond., p. 89, pl. IX., Figs. 1-3.

Observations—This species was first described from Kangaroo Island, S. Australia. It is a well known living form in Victorian swamps and lakes, and I have examples from the Yering Flats, near Lilydale.

The carapace of *C. mytiloides*, seen laterally, appears to be generally rather broader than in the majority of living specimens, but this difference is only sub-varietal. Average length of carapace, 3.2 mm.; breath, 1.4 mm., The type specimen of Dr. Brady, supplied by Prof. Tate, has a length of 5 mm.

Occurrence.—In the Boneo Swamp deposit this species is very abundant.

Cypris sydneia, King. Plate IV., Figs. 6, 6*a*.

Cypris sydneia, King, 1855, Proc. R. Soc. Tasmania, vol. III., pt. I. p. 65, pl. X. Fig. M.

Cypris ciliata, Thomson, 1879, Trans. N.Z. Inst., vol. XI. p. 253, pl. XI. Fig. A, 1*a-g*.

Cypris sydneia, King, G. O. Sars, 1894, Vidensk, Selsk, Skrifter. I. Math. Nat. Kl. No. 5, p. 27, pl. IV., Figs, 2*a-c*. Id., 1896, Freshwater Entom. from neighbourhood of Sydney, Kristiania (Alb. Cammermeyers Forlag), p. 50.

Observations.—*C. sydneia* was originally described from specimens taken in a swamp near Woolloomooloo Bay, Sydney, and Mr. Whitelegge collected it from Bourke Street, Sydney. The New Zealand localities are—lagoons in the neighbourhood of Dunedin; a pond at Eyreton, North Canterbury district; ditches at Kaitaia, N. Island.

The present examples are quite typical, and the shape and position of the muscle-spots agree with the figures given by Sars, of the New Zealand specimens. The surface of the shell is sparsely punctate, and from each punctum there is a faint stria directed posteriorly.

Occurrence.—This freshwater species is fairly abundant in the Boneo Swamp deposit.

Cypris tenuisculpta sp. nov. (Plate IV., Figs. 7, 7*a*, *b*.)

Description.—Valve seen from the side, subreniform, highest in front, narrowing slightly to the posterior. Edge view subovate, moderately tumid, more compressed anteriorly. Valves slightly unequal. Dorsal margin roundly angulate near the middle, directly sloping to the extremity. Both ends evenly rounded. Ventral margin incurved at the middle, and curving outwards to meet the evenly rounded anterior border; the latter having a narrow depressed margin. Surface of shell finely but distinctly sculptured with closely set longitudinal and anastomosing raised lines.

Length, 1.3 mm.; greatest width, 0.77 mm.

Observations.—This species closely resembles *Cypris lateraria*, King,[4] especially in the figures given by G. O. Sars[5] from the Sydney examples. The chief difference lies in the superficial sculpture, which in the present species is finely lineate, *C. lateraria* having a granulose surface with scattered tubercles.

Occurrence.—Common in the Boneo Swamp deposit.

Candonocypris assimilis, G. O. Sars. Plate IV., Figs, 8, 8*a*.

Candonocypris assimilis, G. O. Sars, 1894, Contrib. knowledge Freshwater Entom. N, Zealand, Vidensk, Selsk, Skrifter, I. Math. Kl. No. 5, p. 36, pl. V., Figs. 2*a-c*.

Observations.—In outline, seen from the side and above, the fossil specimens perfectly agree with Sars' New Zealand species, which is a freshwater form. The valves are slightly unequal, as seen in at least one of the complete carapaces in the present collection, and the muscle-spots number 7, with 2 arranged slightly forward and below the others. The surface of the shell is marked with excessively fine, elongate reticulae and a few punctations.

The writer would be inclined to place under the above genus Brady's *Cypris viridula*,[6] of which the above appears to be a fuscous variety. The straight dorsal border figured by Dr. Brady

4. *Cypris lateraria*, King, Proc. R. Soc., Tasmania, Vol. III., pt. I., 1855, p. 65, pl. X., G. G.
5. G. O. Sars, 1896. On Freshwater Entom., from the neighbourhood of Sydney, partly raised from dried mud, Kristiania. p. 53, pl. VII., Figs. 3*a-c*.
6. Proc. Zool. Soc. Lond., 1886, p. 88, pl. VIII. Figs 1, 2.

is not always represented, and in other ways, as in the thicker carapace, it seems to be distinct from *Ilyodromus*, in which genus G. O. Sars has more recently placed it.

Sars' specimens were hatched from dried mud taken from lagoons in the neighbourhood of Dunedin. A female measures 1.6 mm. in length. The present examples have a length of about 1.4 mm.

Occurrence.—Abundant in the Boneo Swamp material.

Fam. CYTHERIDAE.

Genus CYTHERE, Müller.

Cythere lubbockiana, G. S. Brady. Plate IV., Fig. 9.

Cythere lubbockiana, G. S. Brady, 1880, Rep. Chall. vol. I. pt. III. Zool. p. 68, pl. XIV., Figs, *6a-d*. Chapman, 1914, Proc. R. Soc. Vict. vol. XXVII. (N.S.), pt. I. p. 36, pl. VII., Fig. 17.

Observations.—The present example of this marine ostracod appears to be typical in all essentials as form, outline and ornament, with a minor exception that the pittings are replaced by smaller punctuation, as in *C. acupunctata*, Brady.[7] As a living species, it is recorded from Booby Island, Torres Strait, in 6-8 fathoms.

Fossil specimens have been recorded by the writer from the Miocene and Pliocene of the Mallee bores, the deepest being 542 feet from the surface; these Miocene deposits, by the way, have been formed in about 100 fathoms.

It is interesting to note the above species under such widely differing circumstances as to age, depth and geographical position. Although not yet recorded from coastal dredgings round Victoria, *C. lubbockiania* probably occurs in its shallow depths; and in times not far distant, this and its allies, along with the marine bivalve, *Erycina helmsi*, were washed in by tidal currents.

Occurrence.—One left valve found in the Boneo Swamp deposits.

Limnicythere sicula, sp. nov. Pl. IV., Figs. 10, 11.

Description.—Valves very small; seen from the side, subrectangular, expanded anteriorly. Hinge-line long and straight; ventral border incurved in the middle. Anterior margin depressed,

7. *Cythere acupunctata*, Brady, Rep. Chall. Vol. I., Pt. III. Zool. 1880, p. 68, pl. XIV., Figs. *1a-h*.

with a broad border marked with radial lines; posterior with a narrow depressed margin. Seen from above, carapace ovate, compressed at the extremities, with a hooked process prominent in the median area. Rising from the middle of each valve, a little in front and towards the ventral margin, the hooked process is seen to curve towards the dorsal border. Below this, nearer the ventral margin, is a rounded prominence or tubercle, and near the dorsal margin, anteriorly and medially are two others, Superficial ornament consists of fine reticulae or pittings scattered closely over the larger part of the valves.

Length, .38 mm.; greatest width, .3 mm.; thickness of carapace, .27 mm.

Observations.—None of the northern species very closely approach the above form, the nearest being *L. monstrifica*, Norman sp.,[8] found living round England, and Pleistocene in the Lincolnshire Fens. This has two large spinous processes, with several smaller spines and ridges. Undoubtedly the nearest allied species is the *Limnocythere mowbrayensis*, Chapman,[9] which the writer recently described from Mowbray Swamp, near Smithton, N.W. Tasmania. In this species, the lateral processes are not so produced, the tubercles differently spaced, whilst the anterior border is not so deep nor broad. Moreover, it attains a larger size than the present species.

Occurrence.—This very minute species is excessively abundant in the Boneo Swamp deposit.

General Remarks and Summary.

An examination of the swamp deposit from this locality in the Schanck Peninsula affords some interesting points for comment. Probably in late Pliocene times, and on to Pleistocene, this area was connected with Tasmania. The immediate progenitors of the freshwater mollusca and ostracoda found in the Boneo deposit must have been living in dune and swamp country, which no doubt extended across Bass Strait. We can conceive this country then connected by way of a chain of swamps running from the

8. *Cypris monstrifica,* Norman, Ann. Mag. Nat. Hist., Vol. IX., 1862, p. 45, pl. III., Figs. 4, 5. *Limnicythere monstrifica,* Norman sp. Brady, Mon. Rec. Brit. Ostrac., 1868, p. 420, pl. XXIX., Figs. 9-12.

9. Mem. Nat. Mus., Melbourne, No. 5, 1914, p. 60, pl. II. Figs. 8*a-c*.

N.W. corner of Tasmania passing northwards to the east of King Island, and joining with the Cape Schanck area.[10]

That there is a slight antiquity to be ascribed to the Boneo deposit seems to be shown by the presence of marine shells, for the existing conditions would appear to preclude their penetration so far inland, unless perhaps by an abnormally high tide. No doubt the actual conditions at the time of deposition were those of tidal swamps, such as may be seen in the coastal lakes of the Ninety Mile Beach in Gippsland.

This marl is not phosphatic, as might be supposed from the abundant remains of ostracoda. An explanation of this may be found in the fact that those forms which do occur are all thin-shelled, and of the more purely calcareous type of freshwater genera.

The organic remains found in this marl are:—

Pelecypoda.	*Erycina helmsi*, Hedley.
Gasteropoda.	*Coxiella striatula*, Menke sp.
	Bullinus acutispira, Tryon sp.
Ostracoda.	*Cypris mytiloides*, G. S. Brady.
	,, *sydneia*, King.
	,, *tenuisculpta*, sp. nov.
	Candonocypris assimile, G. O. Sars.
	Cythere lubbockiana, G. S. Brady.
	Limnicythere sicula, sp. nov.

EXPLANATION OF PLATES.

PLATE III.

Fig. 1.—*Erycina helmsi*, Hedley. Left valve. × 10.

,, 2.—*E. helmsi*, Hedley. Interior of left valve of another specimen. × 10.

,, 3.—*Coxiella striatula*, Menke sp.

,, 4.—*Bullinus acutispira*, Tryon sp. × 5.

,, 5.—*Cypris mytiloides*. G. S. Brady. Right valve, 5*a*, ventral edge view of the same. × 26.

10. In Dr. F. Noetling's paper on the Antiquity of Man in Tasmania (Proc. R. Soc., Tasmania, 1910), that author, on plate I., Fig. 6, shows the Tasmania-Victorian coastal contours, as would appear from an uplift of 40 fathoms of the present sea bottom in the Strait. The tongue of land thus brought up would form a direct connection from the Smithton (N.W. Tasmania) district to the Boneo (Cape Schanck) locality, and this view helps considerably to explain the theory here advanced, that the Boneo fluviatile fauna was, in part at least, derived from a Tasmanian one.

PLATE IV.

Fig. 6.—*Cypris sydneia*, King. Right valve, showing muscle-spots, 6*a*, ventral edge view. × 26.

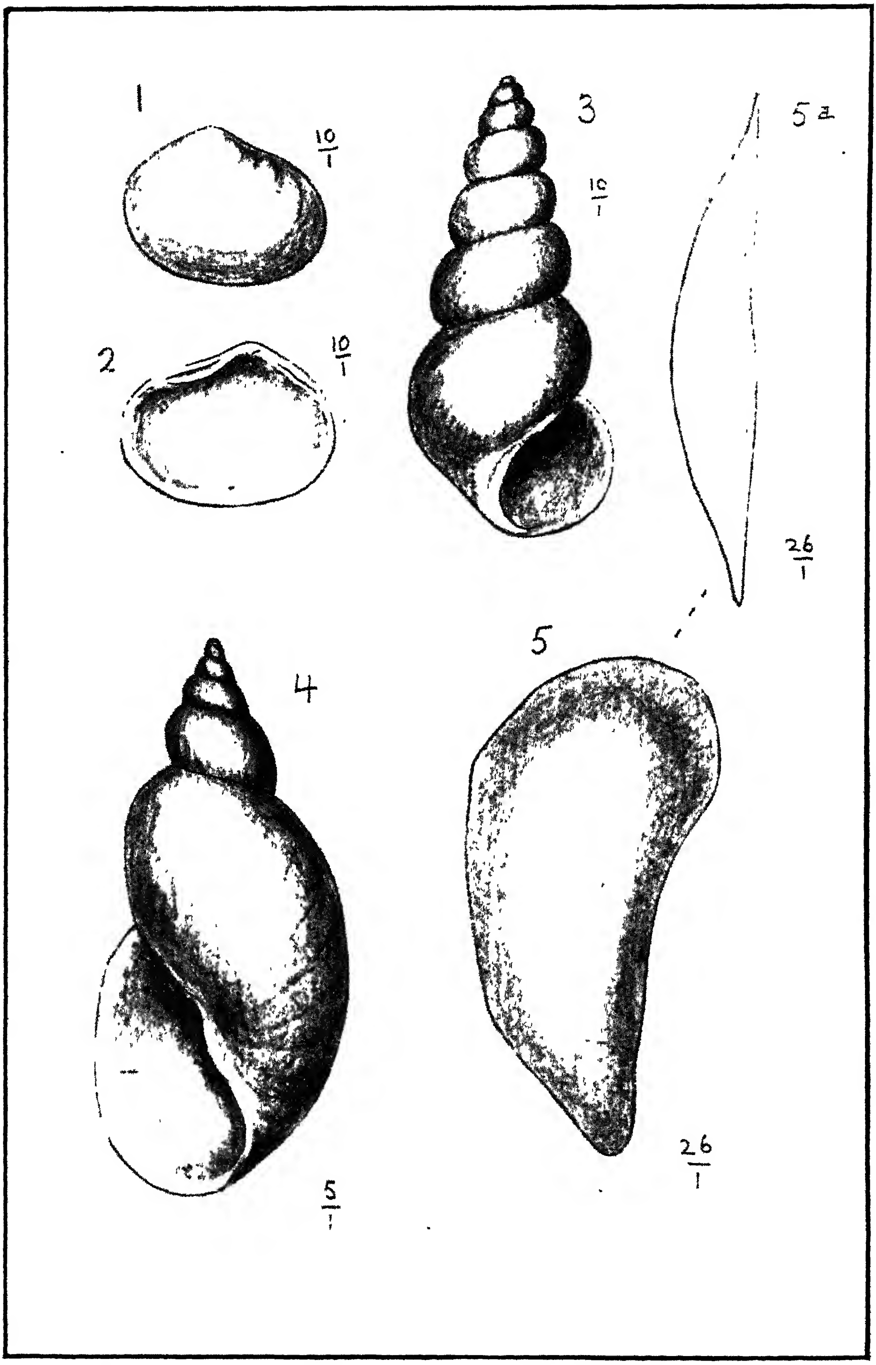
,, 7.—*Cypris tenuisculpta*, sp. nov. Right valve, × 26. 7*a*, ventral edge view of carapace, × 26. 7*b*, magnified view of ornament. × 78.

,, 8.—*Candonocypris assimile*, G. O. Sars. Left valve, showing muscle-spots. 8*a*, ventral aspect of carapace. × 26.

,, 9.—*Cythere lubbockiana*, G. S. Brady. Left valve. × 52.

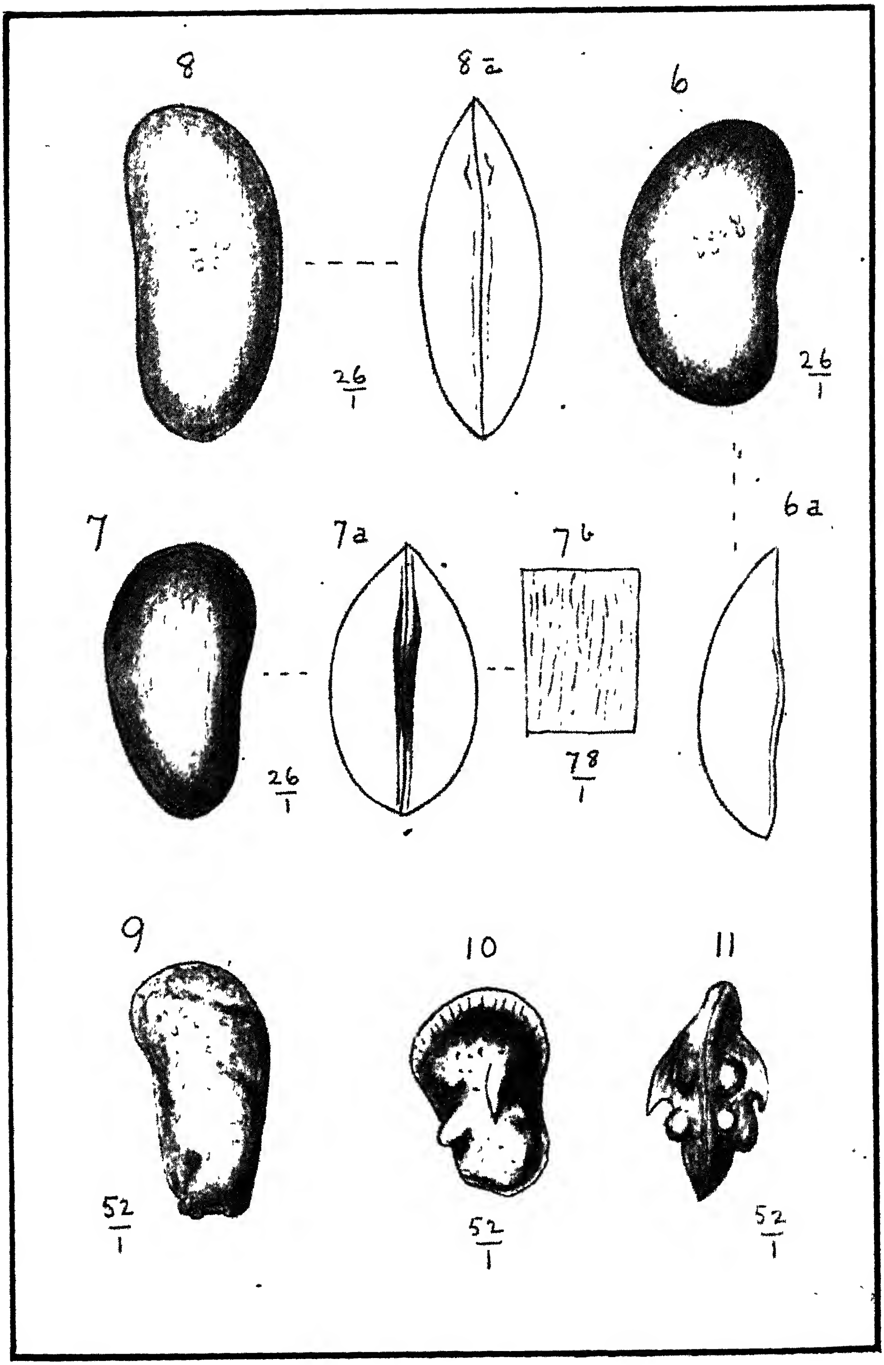
,, 10.—*Limnicythere sicula*, sp. nov. Right valve. × 52.

,, 11.—*L. sicula*, sp. nov. Edge view, dorsal aspect. × 52.



F.C. del. ad nat.

Pleistocene Fossils: Boneo Swamp, C. Schanck.



F.C. del. ad nat.

Pleistocene Ostracoda: Boneo Swamp, C. Schanck.

[PROC. ROY. SOC VICTORIA, 32 (N S.), PT. I, 1919].

ART. VII.—*The Diabases and Associated Rocks of the Howqua River near Mansfield, with reference to the Heathcotian Problem in Victoria.*

BY E. O. TEALE, D.SC., F.G.S.

With an account of the Petrography of the Diabases by
Prof. E. W. Skeats.

(With Plate IV, 4 Text Figures and Map).

[Read July 10th, 1919].

Contents.

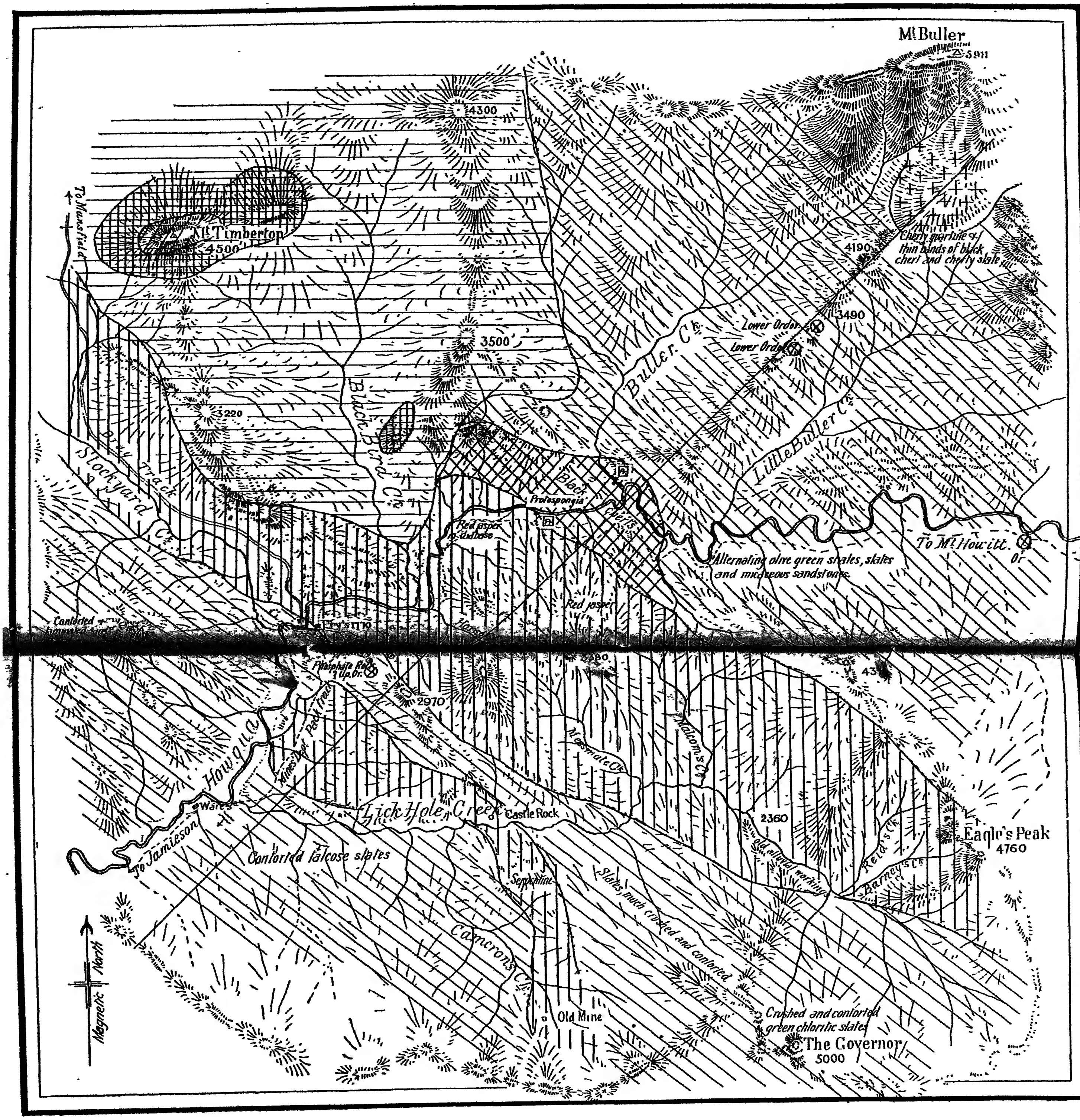
1.—Introduction.

The existence of serpentine and associated basic igneous rocks in the Howqua River to the south-west of Mount Buller was first referred to by Mr. A. M. Howitt,[1] in 1907, in the Records of the Geological Survey in a short note with an accompanying sketch map. Mr. Howitt's visit was an extremely short one, allowing only about a day in the field, and his main object was to report on the supposed occurrence of phosphate of alumina similar to that found near Mansfield. He, however, was able at the same time to note the outcrop of a considerable extent of basic igneous rocks and black cherts. The latter he regarded as probably Heathcotian, on account of their resemblance to similar cherts at Heathcote, which had then been recently placed in that group by Professor Gregory.[2] The igneous rocks he described as amphibolites, which he regarded as intrusive into the Lower Palaeozoic and of Devonian age. He also obtained a graptolite from the Palaeozoic slates which the late Dr. T. S. Hall referred to as a Monograptus,[3] thus indicating Silurian strata. The amount of information collected by Mr. Howitt in a short time, and in such rough and mountainous country, is remarkable. The writer having spent considerable time in the Mount Wellington district in Gippsland, examining the area where serpentine and associated Upper Cambrian limestones occur, came to the conclusion that an important axial line existed in the Wellington region. The extension of the line to the north passes through inliers of closely similar rocks on the Howqua, and at Dookie.

When, therefore, Professor Skeats suggested that I should take up the study of the Howqua region, with the assistance of a Government Research Scholarship, I was very glad to avail myself of the opportunity. I would like at this stage to specially express my indebtedness to Professor Skeats for his interest and assistance in this work. He not only visited the out of the way region on the Howqua, spending about a week in the field with me, but very kindly conducted me over the Lancefield and Heathcote areas, which may be looked upon as the type occurrence of the much debated Heathcotian series.

This work has been invaluable for comparative purposes in dealing with the Howqua region. In the Geological Laboratory of the University, too, I have had advantage of full access to the numerous slides and hand specimens from these regions. It is very helpful

GEOLOGICAL SKETCH MAP, HOWQUA HILLS
SOUTH EAST OF MANSFIELD



LOWER PALÆOZOIC

DIABASE	Heathcotian.	
CHERT ⊡ *Protospongia*	Heathcotian.	
SLATE AND SANDSTONE	Cambrian ? to Silurian. ?	⊗ *Graptolites, L.Ordov. to Silurian?*
GRANO-DIORITE	Devonian	

DACITE-PORPHYRY	Devonian

Uᴾ PALÆOZOIC

RHYOLITE	Lower Carboniferous
SANDSTONE, CONGLOMERATE AND PURPLE SHALE	Lower Carboniferous

Scale. 40 30 20 10 0 40 80 120

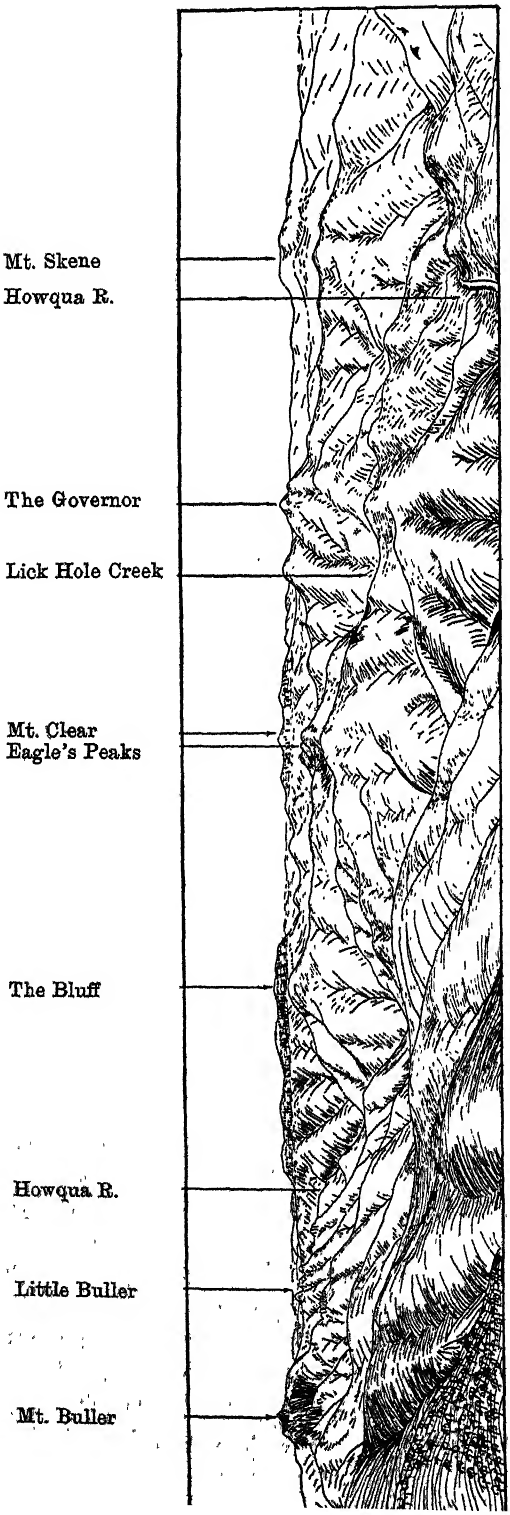
Chains.

therefore to be able to treat the new area in a comparative manner with the better known regions. While there are certain gaps and differences in the Howqua region, as compared with Lancefield, Heathcote and the Dolodrook, near Mount Wellington, many of the comparisons are strikingly similar. It is possible to match many of the special rocks of Heathcote so closely that were the specimens not labelled, it would be impossible to distinguish them from each other.

The problems of the Heathcotian series and the controversial questions wherein Professor Skeats, Mr. E. J. Dunn, Professor J. W. Gregory, and the late Dr. A. W. Howitt either agreed with or differed from each other, have been ably set out by Professor Skeats ([4] and [5]), so that it will only be necessary to enumerate here in due place those special aspects which call for consideration in conjunction with the Howqua area. Many important features in the Lower Palaeozoic history and structure in Victoria are dependent on the elucidation and interpretation of the origin, age and relationships of the various rocks in the scattered inliers of diabases and cherts, now generally included in the Heathcotian series. Regarding this series, field work proves that the Heathcotian conformably underlies graptolite bearing Lower Ordovician rocks, and on field evidence therefore it might be Lower Ordovician or Cambrian. It is on the reconsideration of the Dinesus material on which the original claim for a Cambrian age, subsequently abandoned, is now reasserted, and appears to be established, that it becomes necessary to include the lowest beds generally known as Heathcotian in the Cambrian.

2.—General Location of the Howqua Region.

The area under consideration lies to the south-east of Mansfield just within the rough mountainous region of the central highlands of Victoria. It is distant by road from Mansfield about 22 miles. For 12 miles, as far as Merrijig, on the Delatite River, the road is good, thence the route follows an old track little used, and in a very poor state of repair. By this a steep ascent is made over the shoulder of a ridge overlooked by Mount Timbertop, to drop down into the deep mountainous valley of the Howqua, a striking contrast in its rugged and almost uninhabited character from the open park-like grazing and farming district of Mansfield.



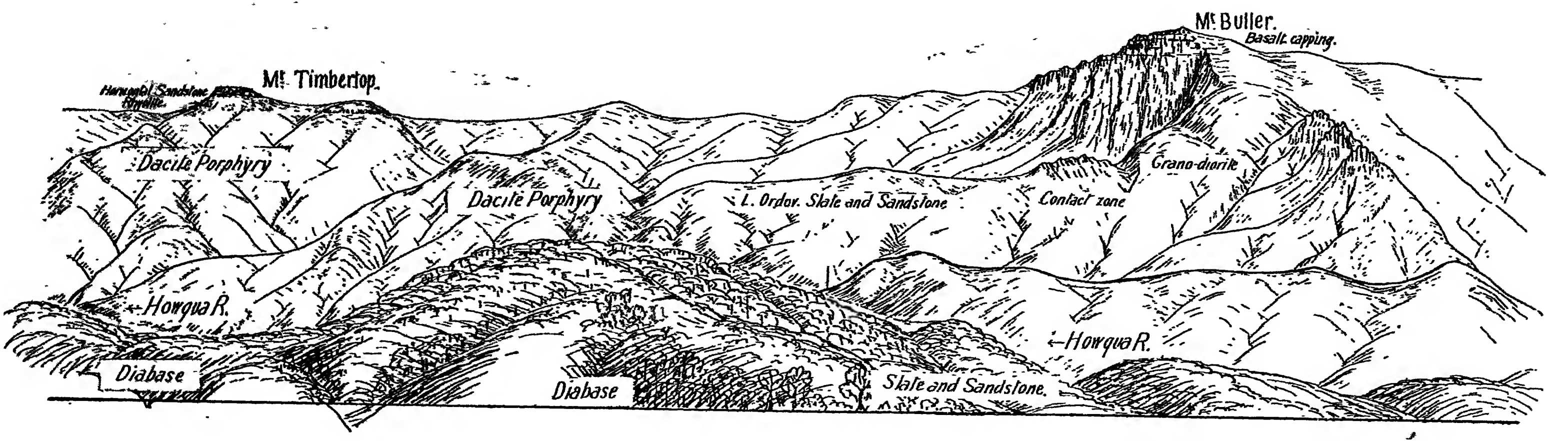
CENTRAL VICTORIAN HIGHLANDS,
HOWQUA REGION.
Sketch from Mt. Timbertop from east to south showing stage of dissection and remnants of overmantle of horizontal or relatively flat lying rocks.

3.—Physiographical Features.

Physiographically, the Howqua area is in an interesting position. It lies near the northern edge of the great central highland belt of Victoria, close to the wide and striking sunkland of the Mansfield district, the development which has had such a remarkable and interesting effect on the history of the river system of this region, the details of which have been ably discussed by Fenner.[6]

Standing on the commanding viewpoint of Mount Timbertop, at about 4500 feet, the general survey of the physiography is particularly interesting, and is scenically both grand and varied. (See Fig. 1.) To the south and east especially the view is most imposing, looking out over the deep Howqua Valley, across the fretted and dissected northern portion of the central plateau, the highest portions of which rise to close on 6000 feet. Mount Buller, the nearest, about four miles to the east, at 5911 feet, present a precipitous front to the west, and forms, with its basalt capped summit, a striking remnant of the old plateau, with the valleys of the Delatite and the Howqua on either side 4000 feet deep. At Timbertop the observer is standing in a small outlier of the flat lying Upper Palaeozoic strata, with the frequently associated rhyolite at the base. To the east and south-east he looks over a vast extent of deeply dissected country, from which the great overmantel of hard, almost horizontal, rocks has been removed, exposing the underlying highly inclined Lower Palaeozoic rocks, chiefly slate and sandstone. The central watershed of the State, known as the Main Divide, lies about 20 to 30 miles distant in this direction, and presents a precipitous and ledged front, due to the same more or less horizontal strata as those on Timbertop. Mounts Magdala, Clear and Macdonald, are the most noteworthy points, while the Bluff of similar structure, distant about ten miles, adds to the rugged character of the scene. Should these mountains be snow-covered, as they frequently are in the winter, the ledged character is generally emphasised.

The whole view in this direction, and as far round as Mount Torbreck to the south-west, about 25 miles away, overlooks the basin of the Upper Goulburn and its tributaries. It may be described as a mountainous region of high relief in an advanced stage of dissection. The original plateau character has been almost obliterated, only restricted ridges within the basin, which rise to about 5000 feet, remain to indicate its former features. The old



SKETCH FROM EAGLE'S PEAK LOOKING NORTH TO NORTH WEST.

HOWQUA VALLEY.

plateau is best preserved round the margin along the main Divide. These relatively flat, elevated areas at 5000 feet and over are locally known as snow-plain country. They form summer feeding grounds for cattle during a few months of the year. The Howqua valley is one of the main cattle routes to these summer grazing areas from the low country. A bridle track follows its course towards the headwaters, where it rises to the open grassy plain near Mount Howitt. The economic value of the region does not lie in its possibilities from a point of view of settlement. Both from an agricultural and pastoral point of view its capabilities are almost negligible, but it forms an important collecting ground and store-house for water supply. It is here that the Goulburn gathers its waters, the value of which for irrigating its fertile alluvial plains is now being widely recognised.

4.—General Geology.

The area specially considered from a geological point of view lies on either side of the Howqua River, with Mount Buller in the north-eastern corner, and comprises about 60 square miles of country. The diabases and associated rocks, which are specially referred to in this paper, cross the tract from north-west to south-east, which is the general trend or grain of the structure as a whole.

One great handicap to investigation in this region apart from its uninhabited and mountainous character was the absence of any map suitable for the work in hand. A surveyed traverse of the Howqua River was kindly supplied by the Lands Department, and with this as a basis, the rest of the topography was sketched in by means of prismatic compass methods, which was the best that could be done under the conditions.

The rocks of this region, with the exception of a small outlier of Kainozoic basalt on the summit of Mount Buller referred to by Fenner[7] are entirely Palaeozoic, but they range in age, probably from Cambrian to Lower Carboniferous, and include both sedimentary and igneous rocks. They may be conveniently considered first in chronological order, starting with the oldest. (See Fig. 2.)

5.—Lower Palæozoic.

This includes rocks which range from Cambrian to Silurian, covering more than three-fourths of the area under consideration, but the exact mapping of the boundaries is rendered very difficult

on acount of the intense folding and crushing to which the series as a whole has been subjected, together with the sporadic and apparently erratic distribution of the fossils, which are mainly graptolites in poor state of preservation, and *Protospongia.* The only fossils obtained from the Cambrian in this region are *Protospongia*, and possibly radiolaria from black cherts similar to those of Heathcote.

Cambrian (Heathcotian Series).

The rocks of this series fall into two groups:—

1. Basic igneous rocks (diabases in part), and associated tuffs, with their alteration products.
2. Protospongia cherts.

A.—The Diabases.

1. The basic rocks referred to here form an important central occurrence in the area under consideration. There are two belts, more or less parallel, but of unequal size, both, however, with a general north-west to south-east direction. The largest and longest starts outside of the area at least a couple of miles to the north-west, and passes out of the map in the south-east, where its extension has not been examined. Its greatest width is about 1¾ miles; the outline is somewhat irregular along portion of its north-eastern side, where it comes in contact with the dacite porphyry, but otherwise the junction and trend conform closely with the general strike of the enclosing sediments.

The smaller belt is shorter and narrower, and ends bluntly on the Howqua, as shown on the map. It would appear to diverge somewhat in direction from the larger belt towards the south in the Cameron's Creek area, which has, however, been only imperfectly traced.

In general, the boundary of these rocks is readily traced in the field, on account of the sharp soil change from the rich dark red of the diabase to the poorer slaty soil of the surrounding rocks. The open, park-like and grassy slopes of the diabase, too, are often in striking contrast to the closer forest with scrub undergrowth of the sedimentary rocks, so that from suitable vantage points the general bearing and limits of the two formations can be distinctly observed from a considerable distance. This is quite analogous to the "clear country," of the serpentine area in the Dolodrook.

The *Protospongia* cherts bound the diabase along the eastern side of the main mass, forming a well-defined belt, about half a mile wide. Numerous specimens, showing the characteristic cruciform spicular arrangement of *Protospongia*, were found in the field in these cherts, and a microscopic section, No. 78, from this belt of cherts, displays well the abundance of the sponge spicules embedded in a dark, largely chalcedonic ground mass. (See Microphoto Plate I., Fig. 3.)

In the Heathcote area Dr. Howitt held that the silicification of corresponding rocks was a metamorphic effect, due to the intrusion of the diabase, an interpretation which is dissented from by Professor Skeats, who shows good reasons for regarding them in part as altered submarine tuffs, silicified by metasomatic action, the adjacent igneous rock being considered as mainly contemporaneous lava flows.

The features are closely analogous here, where the *Protospongia* cherts are found. These fossiliferous cherts have not been recognised along the western boundary nor along the contact of the smaller diabase occurrence. In general, the western junction of the main mass is marked by much crushing and shearing, with other accompanying alterations in both the igneous and the sedimentary, but nothing attributable to contact alteration has been noted. Shistose talc rock is abundant in the valley of the Stockyard Creek, and elsewhere, close to the junction. An important section is exposed in the bed of the Howqua at the foot bridge, where the old dray track from Merrijig ends. The diabase crosses the river in a north-west direction, just above the bridge, forming a bar, and an interesting series of intensely crushed rocks of somewhat varied character can be traced more or less continuously from within a few yards of the contact down stream for about three chains. A short break of about two chains intervenes, where the exposure is masked, and then crushed black slate follows, forming a conspicuous cliff, at the bend of the river. The crush zone here is at least five to six chains wide. A noteworthy feature is that the rock adjoining the diabase shows not the slightest contact alteration at a distance of less than a yard from the junction. Intensely crushed and contorted rocks are the general rule along the contact. This feature, together with lithological and fossil differences of this zone compared with that in the eastern edge are worthy of note, and will call for further comment later, when dealing with the sedimentary rocks and general structural considerations.

(*a*). *Normal Diabase.*

The diabasic rocks show some variation in character from a somewhat doleritic type to that of a dense basalt, the latter being the dominant type. The dense forms are almost identical in features with those of Heathcote.

Though the sections at the Howqua do not show so clearly the same interbedded succession, the character and occurrence of the diabase, and that of the associated cherts are so similar that the assumption is reasonable that here, too, they represent similar submarine lavas, and tuffs, or interbedded cherts.

CHEMICAL ANALYSES OF DIABASES
By E. O. Teale

	Howqua		Heathcote
	No. 15	No. 25	No. 630
SiO_2	46.44	58.17	55.77
Al_2O_3	15.71	13.15	11.23
Fe_2O_3	.53	3.18	1.82
FeO	11.21	8.61	10.11
MgO	8.61	0.91*	7.94
CaO	12.3	6.7	4.64
Na_2O	2.5	7.00	4.91
K_2O	.21	0.41	.73
H_2O+	.21	0.33	.55
H_2O-	2.54	1.34	1.91
TiO_2		0.8	0 22
	100.46	100.61	99.80

* Note low MgO content

No. 25.—SODA, RICH TYPE.

Mineral.	Norm. %	Group.	%
Quartz	.72	Q.	Salic. 65.17
Orthoclase	2.22	F. 64.45	
Albite	59.21		
Anorthite	3.07		
		L.	
Diopside	28.0	P. 31.56	Femic 4.55
Hypersthene	3.56		
Magnetite	4.4	M. 4.55	
Ilmenite	.15		

Class $\frac{\text{Sal.}}{\text{Fem.}}=\frac{64.45}{31.56}<\frac{7}{1}>\frac{5}{3}=$ Class 2. Dosalane.

Order $\frac{\text{Q.}}{\text{Fem.}}=\frac{.72}{64.45}<\frac{1}{7}=$ Order 5. Germanare.

Rang. $\frac{K_2O+Na_2O}{CaO}=\frac{117}{120}<\frac{5}{3}>\frac{3}{5}=$ Rang. = Alkali Calcic. Ilmenose.

Sub-Rang. $=\frac{K_2O}{Na_2O}=\frac{4}{113}<\frac{1}{7}>=$ Sub-Rang. = Persodic. Beerbachose.

(b) The petrography of the diabases, including soda-rich types.

(By Professor E. W. Skeats.)

Reference to the chemical analyses shows that diabases of fairly normal composition are present. The analysis of No. 15 shows that as regards the alkali content, it is normal, but has a high content of the alkaline earths, especially of lime. No. 25, however, on analysis proves to have a very high soda content, and is unusually low in lime. It evidently has suffered albitization, and shows that the spilite type of magma is represented among the Howqua diabases, and the analysis of a diabase from Heathcote is also relatively rich in soda.

The petrographic descriptions which follow show that albitization, silicification, chloritization, the production of secondary hornblendes from augites, the formation of carbonates, and the development of the mineral lawsonite, are features of fairly common occurrence among the Howqua diabases, which in hand specimen, may not appear to be specially altered.

The term diabase, used to describe these rocks, has been found useful to retain, although it is now clear from their field relations and principal petrographic characters that they are mainly submarine lava flows and ashes.

No. 11.—Diabase from the ridge between Howqua River and Lick Hole Creek. The rock consists of pale-coloured augite to the intent of about 3-5th, and a very kaolinized felspar to the extent of about 2-5th of its volume. The augite is diallagic in part. Both augite and felspar seem to have started crystallizing simultaneously, as each in places is porphyritic, and in other places is moulded on the other. The felspar is too cloudy for specific determination, a little ilmenite, altered to leucoxene and of chlorite after augite, is also present. Some secondary clear to cloudy chalcedony is also present, partly replacing felspar.

No. 12.—Locality east of No. 11, but on the same ridge. The rock is moderately coarse-grained; about two-thirds consists of felspar, mostly as relatively large rectangular phenocrysts, with a small amount of later micro-spherulitic felspars moulded on them. The phenocrysts are mainly albite, or Ab_{90} An_{10}, having a refractive index as low as the mounting balsam, which is less than 1·53. Some felspars are untwinned, possibly 010 sections, with extinction angles, ranging from 3°-19°. Others show carlsbad or albite twinning, or both. Symmetrical extinction angles of 15°-18° occur on the albite lamellae. Some of the felspar is saussuritized to granules of epidote and zoisite. The bulk of the felspar slightly preceded the augite in crystallizing, but in one place augite and felspar are in micrographic intergrowth. A fair quantity of ilmenite occurs in elongated crystals, and is more or less altered to leucoxene. Clusters of radiating, brown, green or bright red micaceous products occur. In one place crystals of a secondary red micaceous mineral product radiate from the ilmenite at right angles and granular epidote is also associated with it. A little pleochroic aegirine-augite, with extinction angle of 29°, is also present. The rock may be described as an albite diabase.

No. 15.—Compact diabase, from Four Mile Creek (analysed). (See Plate I., Fig. 2.) There is very little felspar present, and this consists of lath-shaped crystals and larger areas now altered to zoisite and minute secondary mica flakes. The rock consists mainly of granular augite, with some areas of chlorite, a fair quantity of ilmenite altered to leucoxene, and some granular pale brown sphene.

This mineralogical content is in agreement with the high lime and magnesia, and low alkali content of the analysis.

No. 16.—Spotted diabase from Four Mile Creek. In the hand specimen light circular spots are noticeable, but are much less prominent under the microscope. However, slightly lighter areas can be seen, and appear to be due to the relative crowding of minute more or less altered lath-shaped felspars, while a relatively smaller amount of augite and chlorite occur in these areas than in the rest of the rock. One large phenocryst of plagioclase now consisting mainly of chlorite and secondary felspar, was noticed, and minute granular oxide of iron, with a little carbonate, occurs. The augite is mostly granular in habit, with undulose extinction.

No. 17.—Compact diabase from smaller diabase outcrop on the track to Ware's, and south of Fry's.

In this rock much recrystallisation under pressure has occurred. Most of the augite has recrystallized as fibrous secondary hornblende, with light to dark green pleochroism, and extinction angles ranging from 11° to 21°. The felspar has recrystallized to water clear secondary felspar, with enclosures of secondary hornblende needles. Ilmenite in large skeleton rhombohedra altered to leucoxene, is fairly abundant. Some interstitial secondary calcite is present. The extensive recrystallization of the rock is no doubt referable to its occurrence in a crushed zone, south of Fry's, and it resembles some of the recrystallized diabases of Heathcote and Mt. William, near Lancefield, but is hardly so altered as the epidiorites of Ceres, near Geelong, since some relic structures in the form of original augite and felspar are still noticeable.

No. 18.—Diabase, south-east of No. 17.

A diabase which has suffered fairly complete recrystallization to fibrous hornblende, and secondary water clear felspar. In the process a considerable amount of granular and dusty magnetite has separated out.

No. 22.—From main diabase mass, Lick Hole Creek, and east of isolated crushed diabase mass. A relatively coarse-grained type with no signs of recrystallization under pressure. Coarse plates of augite and cloudy felspar form the bulk of the rock, with chlorite and clear felspar as secondary products.

No. 25.—Soda rich diabase (analysed), Lick Hole Creek, one mile north of the Governor, and near the south-east end of the main diabase mass. (Micro. Photo., Plate I., Fig. 1.)

About 2-3rds of the rock consists of felspar in large and small prismatic, quadrate or irregular crystals. Simply twinned and untwinned crystals are abundant, and some show lamellar twinning. The low refractive index, positive sign, and biaxial figure show that albite or albite-oligoclase predominates. All the felspars are clear, and some contain secondary hornblende and chlorite, suggesting recrystallization. Some original augite remains, but much is altered, either to normal hornblende or green pleochroic fibrous actinolite. Sphene, epidote and zoisite occur in granules. Brown clusters of radiating biotite crystals occur, and some calcite, a little quartz, and a few elongated prisms of apatite are present. The high albite content of the rock is confirmed by the chemical analysis, but it is difficult to reconcile the relative abundance of ferro-magnesian minerals with the strikingly low magnesia content recorded in the analysis.

No. 40.—Diabase on spur, east of Blackbird Creek, north of Howqua River, and about one mile E.N.E. of Fry's. A rock type in which augite and its alteration product chlorite predominate and felspar is in subordinate amount. Some of the felspar probably preceded the augite in crystallizing, and recrystallization of felspar, with resulting inclusion of chlorite has probably occurred. Ilmenite granules have changed to sphene.

No. 41.—Diabase from Castle Rock, Lick Hole Creek. A diabase which has suffered much secondary albitization. Augite is altered to pale and to brown secondary hornblende. The original felspar is now quite cloudy, chlorite is developed, and an irregular vein of secondary albite or albite-oligoclase traverses the section. It looks like quartz in ordinary light, but is identified by the presence of some lamellar twinning, by its refractive index, which is less than 1·53 and by biaxial figures with positive signs. Ilmenite, more or less altered to sphene, and hematite, are present. The albite in the vein occurs in clear interlocking crystals, associated with calcite, and with fibrous secondary hornblende.

No. 42.—Diabase, near No. 41. A rock similar to No. 41, but with only a minute vein of secondary albite, traversing the section.

No. 72.—Silicified fine-grained diabase from Four Mile Creek, near the massive black bedded cherts at the north-east margin of the main diabase mass. In the fine-grained diabase area a little augite remains, but most of it is altered to chlorite and secondary hornblende. Lath-shaped, water clear felspars, with chlorite inclusions occur. Sporadic secondary quartz occurs in granules in the mass of the diabase, but in over half the section the diabase has been completely replaced by a radial and granular aggregate of chalcedonic silica, with some coarser grained quartz crystals. The rock has a spotted appearance, due to greater concentration of felspar laths in roughly circular areas.

No. 73.—Diabase from Four Mile Creek, near to 72. This rock is rather coarse grained. Brown unaltered augite and large lath-shaped albite or albite-oligoclase, many with chlorite inclusions, form the bulk of the rock. Opaque iron oxide is fairly abundant, and large areas of chlorite, apparently not derived from augite, occur.

No. 107.—Diabase from spurs south of Barney Creek, at south-east end of main diabase mass. The rock may be described in its present condition as a micrographic quartz-diabase. Some original

augite remains, but most of it has changed to secondary hornblende. Chlorite is abundant, ilmenite altered to sphene is prominent, porphyritic crystals of albite or albite-oligoclase, one or two prismatic crystals of apatite, and some relatively large irregular quartz crystals occur. The background is a beautiful micrographic intergrowth of quartz and albite, the latter showing lamellar twinning in places, and a refractive index lower than quartz. The micrographic background and the larger quartzes both appear to be of secondary origin.

No. 108.—Diabase from spur south of Barney's Creek, Upper Lick Hole Creek Valley, at south-east end of main diabase mass. A diabase of moderate grain size, in which very complete secondary alterations of the original minerals, augite, felspar and ilmenite have occurred. A little original grey brown augite remains, but most of it has been changed to secondary hornblende, some of it prismatic to tabular, some to fibrous actinolite, some to vivid green chlorite in clusters of radiating fibres. Quartz occurs in scattered granules, and in micrographic intergrowth with augite and with chlorite. This quartz may be primary or secondary. Much secondary quartz occurs, more or less completely replacing the lath-shaped felspars which, however, still show the outlines of the crystals and the positions of the twin lamellae in a remarkable way. An irregular vein, about $\frac{1}{8}$ inch wide, traverses the rock, and consists partly of quartz, but mainly of colourless to cloudy prismatic and radiating crystals of lawsonite, a hydrated silicate of lime and almuminium. The mineral is recognised by its positive sign, and biaxial character, its high refraction and polarization colours up to second order, whereas the quartz shows low neutral tints. The lawsonite is a secondary mineral derived mainly from the alteration of the felspar, but in places is seen to develop from altering ferromagnesian minerals in the mass of the rock. Ilmenite is partially altered to leucoxene, and a little secondary calcite and epidote are also present. No secondary albite was recognised in the rock, and the original felspars are so altered either by becoming cloudy, through incipient saussuritization or replaced by quartz, that their original character is unrecognizable.

No. 109.—Diabase from same locality as No. 108. A moderately coarse grained rock which is free from quartz, but otherwise has suffered much the same changes as has No. 108. The large platy albite or albite-oligoclase felspars have chlorite inclusions. Some augite has developed a diallagic structure, and there is a consider-

able development of secondary lawsonite, principally in clear to cloudy minute radiating crystals.

No. 118.—Diabase from Upper Lick Hole Creek, one and a-half miles N.N.W. of The Governor.

A diabase in which albitization is a marked feature, resulting in the formation of clear secondary platy crystals, and raditaing lath-shaped crystals. The augite is mainly converted to secondary hornblende, some of which is normal, while some is fibrous, pleochroic actinolite. A good deal of calcite occurs, but neither quartz nor lawsonite have been recognised.

No. 119.—Diabase from same locality as No. 118. A coarse-grained type, with cloudy felspars, pale augite, partly replaced by hornblende, and a little quartz.

No. 121.—Diabase from Lick Hole Creek, quarter mile west of No. 118. A rock similar to No. 119, but with an abundance of large opaque crystals of magnetite or ilmenite.

No. 122.—Diabase from same locality as No. 121. A rock almost identical in characters with No. 118.

(*c*) *Platy and Splintery Diabase.*

Some forms of platy diabase appear to be due to a special development of jointing in the diabase. This form was favoured by the natives for making their stone axes, and several small quarries occur close to the road, about half a mile north of the old road terminus. More often they appear to represent altered tuff beds. Rocks of this nature occur at intervals throughout the area, but the outcrops are not readily traced. The most characteristic and tuff like occur on Lick Hole Creek, about a mile above Malcolm's Creek. Here they are somewhat banded, and suggest stratification. The rock is dark green, and of very fine texture in hand specimens, and under the microscope (section 24) shows a very fine textured fragmental structure of minute angular fragments in a matrix which cannot be resolved. Section 23 is a basic platy rock with coarse and fine banding, but is altered, and in parts serpentinized so that its original character is not recognisable, but the probability is that it represents a tuff. The splintery diabase is a fine-grained green variety, which splits readily into long slender splinters, or pencils with angular edges. It is found in contact with massive diabase at the north-western extremity of the small diabase area, a little less than a mile in a straight line south of Fry's

It can be matched exactly with a similar occurrence at Heathcote south of Photograph Knob, where Professor Skeats regards it as an altered tuff.

B. *Agglomerate.*

A well-marked breccia occurs on the east-west ridge between the Howqua and Fry's, and the Lick Hole Creek. It forms one of the prominent points, and is marked Breccia Knob on the map. This rock is a typical breccia, made up largely of igneous fragments, but contains also some banded chert. Sections of the chert examined suggested strongly altered tuff, and were of coarser texture than the *Protospongia* chert. Under the microscope a thin section of the breccia (Section 14) shows it to be made of fragments so dense as to be almost opague, but small pyroxenes present indicate that the material is igneous and represents rapidly cooled lava. If the eruption were submarine, as it is believed the general evidence indicates, the rapid chilling of parts of the lava would be expected.

C. *Alteration Features of the Diabase.*

(*a*) *The Red Jasper.*

The bright red colour of this rock together, with its hardness and durability make it rather a conspicuous and characteristc rock in the recent river gravels in the diabase region, and also an easily recognizable pebble in some of the Upper Palaeozoic conglomerates.

It occurs in situ in the diabase as apparent inclusions,[1] for which they have have been mistaken, but it is clear in the Howqua, as in the Heathcote region, as shown by Professor Skeats, that it represents one of the phases of metasomatic replacement of the diabase. A good section can be studied in the bed of the Howqua River at low water, about one and a-half miles above Fry's, as shown on the map. The irregular shape is typical of patchy replacement areas, and miscroscopic sections occasionally show relic structures of the original igneous rocks, though in general the action has gone so far that all that is seen is an aggregate of secondary quartz and iron oxide stain.

These jaspers occur at intervals along a definite line, bearing from north-west to south-east, that is, coinciding with the general trend of the diabase.

They vary from small aggregates of jasper patches to larger masses of perhaps 50 to 100 square yards in extent. Associated with the normal red jasper there are often other varieties of quartz varying both in colour and texture, milky quartz and granular quartzitic forms being frequently present.

The linear arrangement of these outcrops suggests the occurrence of a shear or fracture zone along this line, which favoured at recurring intervals the access of silicifying solutions. The jasper which is a definite alteration product of the diabase is distinct in character from the black bedded cherts, which are altered stratified deposits.

(b) *The Siliceous-Carbonate Rocks.*

These rocks form a very striking and characteristic alteration product in the diabase area, and are identical in character with similar rocks occurring in Heathcote. In appearance the rock has a somewhat schistose structure due to fine and contorted banding. (Sec. 51.) It has a prevailing brown colour, with greenish streaks due to a substance allied to selwynite or green chalcedony, which also occurs in lenticles and patches. Numerous sections examined by Professor Skeats from Heathcote indicate that this was originally a diabase or diabase tuff which has suffered alteration in two stages. First it was subjected to a carbonating solution, which produced a mixture of iron, lime and magnesian carbonates, and, later, siliica bearing solutions invaded the rock, replacing in part the original carbonate.

Four separate outcrops of this rock have been noted. One is in the bed of the Howqua, at the pack horse bridge, near Fry's—(specs. 51-54); a second about a mile farther down the river, associated with the smaller diabase area; the third is on the track to Cameron's Creek—(Spec. 44)—about a quarter of a mile south of Lick Hole Creek; and the fourth is about half mile to the south-west of this spot—(Spec. 113). The two lastnamed occurrences are in close proximity to a serpentine outcrop, and the first is on a fracture line leading to another serpentine area. It may be, therefore, that the concentration of carbonates in one place may be casually connected with mineral redistribution, which took place during serpentinization.

C. *The Talc Rocks.*

These rocks vary from massive talc rock and talc schist, undoubtedly altered diabase to talcose sediments, which may be altered tuff beds. The latter will be referred to again, when dealing with the lower Palaeozoic sediments. Talc rock is abundant at the north-western end of the diabase area, in the valley of Stockyard Creek, and its greasy nature adds to the difficulty for horse traffic on the steep graded track to the Howqua from Timbertop

Gap, especially in the present bad state of repair of the road. In general it occurs at intervals along the western margin of the large diabase area, and round the edges of the smaller one. Though sometimes massive it is generally schistose and iron-stained. The crushed margins of the diabase appear to have been most favourable for its development. At Cameron's Creek about a mile and a-half south of Lick Hole Creek, a schistose talc rock with very little iron stain appeared to be slightly auriferous. Some prospectors at work during the writer's examination obtained a fair prospect of very fine gold from a trench entirely in this rock.

(*d*) *Serpentine and Chrysotile.*

Three outcrops of serpentine, all of fairly limited extent, have been noted. The largest occurs on a ridge about half a mile south of Lick Hole Creek, in the track to Cameron's Creek. It is of the usual dark green type, and varies from massive to schistose. Isolated grains of chromite have been detected in it, but no quantity of this mineral has yet been found, nor has any corundum been observed in this district, as in the case of the Dolodrook and Heathcote regions. A thin section shows the rock to be completely serpentinized, and it possesses the platy structure of antigorite, and is, therefore, probably due to the alteration of a pyroxene rock.

The second outcrop is about a mile south-east of Fry's, on the western margin of the diabase; its extent is masked here by much surface soil and hill slip material.

This outcrop is noteworthy, because it contains chrysotile asbestos. The increased demand for asbestos during the war, both locally and abroad, has induced much searching after local supplies, and this occurrence has been taken up by Mr. Fry with a view to opening it up to prove its worth. At the time of my visit only shallow hillside cuts had been made. These revealed thin veins of chrysotile traversing the serpentine along numerous joints and slip planes forming a network which at some of the intersections developed into knots or centres of chrysotile. All the material noted was of a slip fibre type—that is, it consisted of somewhat overlapping fibres lying parallel to the joint and slickenside planes. None of the cross-fibre type was observed. With regard to the origin and development of chrysotile veins in serpentine, the subject has been discussed by Graham in Economic Geology.[9] His inquiry leads him to favour the idea that the agents of change for the Canadian occurrences were magmatic siliceous waters derived from neighbouring granitic intrusions.

Twelvetrees,[10] in describing the asbestos occurrence in serpentine at Anderson's Creek, near Beaconsfield, Tasmania, also postulates a causal connection of the origin of the asbestos with a neighbouring granitic intrusion.

At Heathcote and Howqua the rocks have certainly been invaded by siliceous solutions, and in each case granitic intrusions are present in close proximity. It is reasonable, therefore, to suggest at any rate that the vicinity of an acid magna may have provided conditions which were favourable for the remarkable selective metasomatic and other changes, which were wrought along favourable lines and zones in both of these areas. At Howqua, grano-diorite occurs on the southern slopes of Mount Buller, and a mass of dacite porphyry of related age is actually in contact with the diabase between the Howqua and Timbertop.

(e) *Mineralization of the Diabase.*

Another phase in the alteration of the diabase is shown by the siliceous sulphide occurrence at the abandoned gold mine, about a mile south-east of Fry's. The occurrence is an interesting one, and it has been known under different names during its chequered career as a mining venture, but perhaps its best known title is the Great Rand Mine. No accurate survey of this deposit has been made so far as the writer is aware, but like many sulphide occurrences its shape would appear to be irregularly lenticular, consisting of a metasamotic replacement in a fracture zone. The quartz is tough, and very finely granular, and the sulphides are abundantly distributed through it. Iron sulphides, pyrite and pyrrhotite, predominate, but, galena, sphalerite, chalcopyrite and arsenopyrite were noted in small quantity. During my last visit to this region, the mine was being tested by a small syndicate, with the view to determining whether it was possible to treat the ore profitably. The deposit was systematically sampled under the direction of Mr. W. A. T. Davis, of Melbourne, and through the courtesy of Mr. Cottingham, one of the syndicate, I was able to note hurriedly the character of the deposit, as far as the old workings would permit. These reveal a mineralized zone about 300 feet long, in a north and south direction, by nearly 200 feet from east to west.

The mineralization is irregular, and sulphides are found in varying quantities throughout the rock from considerable masses to a mere impregnation. The examination was too short to deter-

mine whether any definite system or plan of arrangement for the mineral material could be recognised, but the observations suggested two sets of fracture lines, or planes, one set about east and west, another approximately at right angles. Along the former especially, mineral solutions have been very active, replacing the original rock with sulphides associated with quartz or calcite. Two active processes accompanying the sulphide formation appear to have been silicification and carbonation. Much of the original rock in places appears to be almost completely carbonated, as is shown in a slide (No. 102), from the southern end of the working. From Mr. Cottingham I have since heard that the result of the sampling indicated an average value for the deposit of about 8 dwts. per ton, which they did not regard as sufficeintly encouraging under the circumstances to lead them to undertake further work.

It is interesting to note that if a north-west to south-west line through this mine be produced in either direction, it follows the trend of the diabase and includes other auriferous occurrences at intervals. The old alluvial workings in Stockyard Creek lie at the north-western end. Another abandoned mine occurs to the south-east, on Malcolmn's Creek, while still further in this direction extensive alluvial workings, long since worked out, are found in the upper portion of Lick Hole Creek. Nothing to suggest a continuous line of lode has been noted along this line, but a probable fracture zone is suggested which provided at intervals favourable access to mineralizing solution. This is in conformity with another parallel line to the east previously referred to, along which siliceous replacements have taken place chiefly resulting in the formation of red jasper.

The Cameron's Creek gold occurrences appear to be of the more normal reef quartz type; at any rate, the adit examined in this area revealed a quartz lode with well defined walls, of decomposed diabase. This is on the southerly portion of the smaller diabase outcrop. A section of the igneous rock (No. 50) showed much chloritization, but traces of an original hornblende were recognizable by cleavage lines preserved in iron oxide; triclinic felspar was recognizable, and secondary calcite was moderately abundant.

A brief report on the mine was made by the late James Stirling[11] in 1888, in which he described the Cameron's Creek reef as consisting of quartz segregations in intrusive diorite.

D. *Lower Palaeozoic Sediments.*

These are found enclosing the diabase on all sides, except where later dacite porphyry or Upper Palaeozoic sediments overlie it at the northern extremity. These rocks are mapped as Silurian on the 8 inch Geological Map of Victoria, and until the writer's examination the only fossil recorded from this region was a *Monograptus* obtained by Mr. A. M. Howitt, and indentified by the late Dr. T. S. Hall.

The present field work has brought to light other graptolites, ranging from Lower to Upper Ordovician and *Protospongia* in cherts identical with those of Heathcote now included in the Cambrian, and possibly also radiolaria in the same cherts. The fact that the graptolites are poorly preserved, and separated by large intervening barren areas, makes the working out of the correct stratigraphical succession in this area very difficult. In fact it would be unwise in the present state of our knowledge in this region to attempt to mark boundaries between the different members of the Lower Palaeozoic. We can only note that the succession probably ranges from Cambrian to Silurian, and no unconformability has with certainty yet been recognised in this region.

At Heathcote no certain line of division can be drawn between the lowest beds of the Ordovician and the uppermost of the Cambrian. The Dinesus tribolite beds form a bench marking the Cambrian, but above them there is a great thickness of unfossiliferous sediments which seem to pass comformably into the Ordovician.

In the area above mentioned, and in the Howqua region, it would appear that there has been a continuous sedimentation from Cambrian, through Ordovician, and possibly, too, into Silurian in the last area. The fossil record is, however, unfortunately very imperfect.

(a) *Lithological Features of the Sediments and Apparent Relationships.*

There are certain broad lithological distinctions which are apparent, and features also with regard to the general distribution which call for discussion.

First, there is a marked lithological contrast on either side of the main diabase area.

On the western side only Upper Ordovician and, possibly, Silurian graptolites[1] have been noted, and these come from a very restricted area. Slaty rocks often somewhat talcose and chloritic prevail, sandstones and quartzites being subordinate. The rocks are frequently intensely contorted, particularly at the "Governor," and a long line to the north west of this.

The unweathered slates were often black, as at the outcrop below the pack-horse bridge at Fry's. By oxidation and leaching, however, they are often almost white.

They only show slight local chertification, and no *Protospongia* has been noted in these cherts.

On the eastern side, however, the black *Protospongia* cherts are well developed, forming a continuous belt up to half a mile in width, directly in contact with the diabase. These cherts stop suddenly to the east and give place to a dark, micaceous and slightly felspathic sandstone, which appears to be quite conformable and then follows a thick succession of olive green phyllitic slates, alternating with sandstone and quartzite. Traversing these rocks across the strike in a north-easterly direction towards Mount Buller, at about one and a-half miles from the cherts, thin black slate bands begin to occur interbedded with the olive green slates and sandstone. Two of these bands have yielded *Tetragraptus* and *Didymograptus*, thus indicating a Lower Ordovician horizon. Continuing still further to the north-east, and approaching the Mount Buller grano-diorite, these sediments give place to belt of dark cherty slates, and fine grained quartzite, often veined with quartz. Microscopic sections of these rocks indicate contact phenomena attributable to the proximity of the plutonic intrusion. These indurated rocks form a very jagged outcrop, to which the rough outline of Little Buller is due.

Following up the valley of the Howqua, the direction is in general easterly, and, therefore, crosses the strike of the same series of sediments in an oblique direction. The Lower Ordovician strata, yielding *Tetragraptus* and *Didymograptus*, have not been noted, but at a few chains west of Eight Mile Creek, indistinct graptolites were found in black cherts. These were too poorly preserved for certain identification, but they suggested *Diplograptus*

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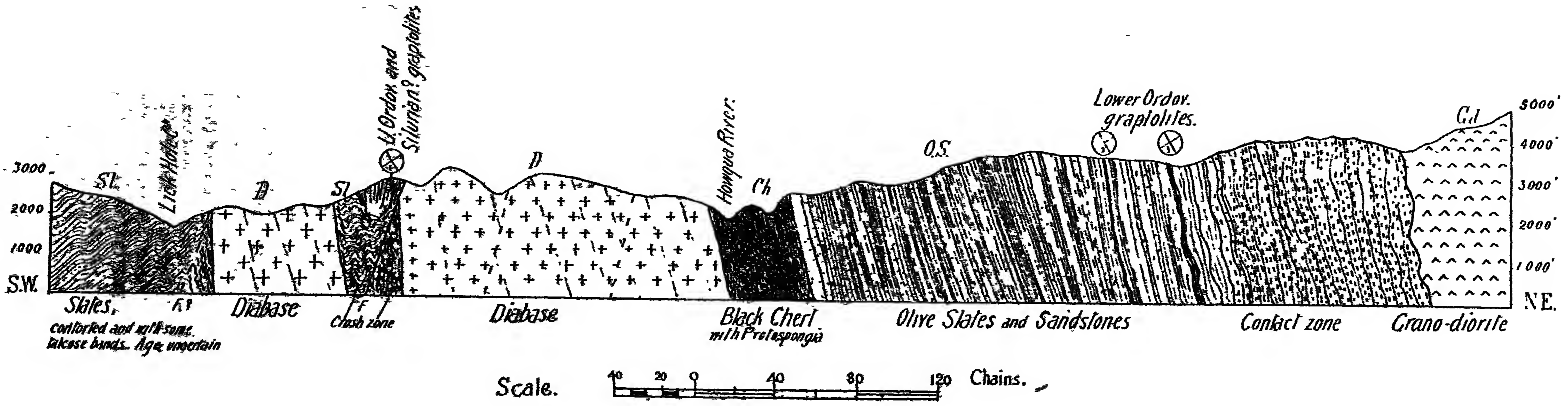
1. The writer has spent days searching along the restricted area where Mr. A. M. Howitt obtained a graptolite, identified by Dr. T. S. Hall as a *Monograptus*, but did not find a single specimen of this genus, though hundreds of specimens of less restricted range were obtained, chiefly *Climacograptus* and *Diplograptus*, with probably *Glossograptus* and other doubtful forms.



SECTION, HOWQUA HILLS.

and *Climacograptus*. If this is correct, they probably are of Upper Ordovician age. These sporadic occurrences of imperfectly preserved fossils are tantalizing, but they indicate that great caution is necessary in interpreting the stratigraphy of the region.

(*b*) *Structure of the Lower Palaeozoic Area.*

In general, the prevailing dip on the eastern side of the main diabase, as far as observed, appears to be consistently easterly, while on the western side it is to the west. The structure, however, is clearly not that of a simple anticline, for the evidence of the fossils on either side, together with the lithological discordance excludes the possibility of such a view.

A faulted anticline, with the fault approximating to the western margin of the main diabase, is suggested, but this requires an enormous down throw on the western side to bury the great thickness of Lower Palaeozoic sediments represented on the eastern side. The Upper Ordovician, and possibly Silurian fossils on the western side close to the diabase, would appear to demand this view, in the absence of any recognised unconformity to afford any other explanation. The presence of the second diabase occurrence to the west offers certain difficulties, however, in the way of this interpretion.

Another alternative would be to assume that the Upper Ordovician, with possibly Silurian, is but a small fragment that has been nipped in by the intense folding to which the area has been subjected. The fossiliferous area is very restricted, further search may extend it, but the writer has spent much time without success looking for fossils in the surrounding strata. It may, therefore, be that the bulk of the rocks which, so far, have proved unfossiliferous, are very much older, and may be Lower Ordovician, or even Cambrian. With the present evidence at hand the matter must be left an open question. (See Fig. 3.)

(*c*) *Phosphate Deposits.*

While searching diligently to obtain graptolites to confirm, if possible, the presence of Silurian, as indicated by a reported *Monograptus* found by Mr. Howitt, Professor Skeats and the writer discovered a phosphatic breccia. This was of considerable interest, because it was the report of phosphatic rock from this district that led to Mr. A. M. Howitt's flying visit. The piece shown to Mr.

Howitt was a loose block, which had been brought to the old mine. As no more could be found in the neighbourhood, it was suggested that it might have come from Mansfield.

The position of the present occurrence is shown on the map. It is only about a mile in a straight line, south-east from Fry's, and less than half a mile south-west from the old mine.

The rock is light-coloured, creamish, earthy fragments predominating, but dark, almost black pieces sometimes somewhat cherty, also occur. Rough stratification is noticeable, and the bed has a defined dip and strike conforming with the enclosing rocks. The outcrop is not continuously exposed at the surface, and has the appearance of being broken and dislocated. The rocks in general in this zone are much disturbed. The phosphatic breccia, however, can be traced at intervals along a distance of about 130 yards, in a north-west to south-east direction.

Wavellite is abundant in thin seams along some of the joint planes, and an analysis of the surface rocks shows that it is an impure aluminous phosphate, containing only about 7% of P_2O_5. This may represent leached material; at any rate, it would be unwise to say that it represents the composition of this rock at a depth. Lithologically, the material does not resemble the Mansfield phosphate rock, which is not a breccia. The organic remains are imperfectly preserved crustaceans of the character of phyllopod-like forms, while those of Mansfield have been referred to as probably Salterella, thus differing also organically. An account of this phosphate deposit has recently been published.[2]

Since *Tetragraptus* has been recorded at Mansfield, it would appear that both Lower and Upper Ordovician graptolite-bearing rocks are closely associated. At the Howqua, the only fossils in the associated beds are graptolites and occasional brachipods, which may be either Upper Ordovician or Silurian, and the phosphate deposits are definitely interbedded with these.

In order to test the relationship of the phosphate deposit to the surrounding sediments, the writer and his father spent a couple of days with pick and shovel putting a trench across the outcrop, the result of which was to prove conclusively that the phosphate breccia is interbedded with the surrounding graptolite-bearing strata. The accompanying section illustrates the relationship.

2. Ernest W. Skeats and E. O. Teale, Aust. Inst. of Mining Engineers, Proc. New Series, No. 32, 1918, pp. 155-165. Fig. 4 is from a block lent by the Aust. Inst. of Mining Engineers.

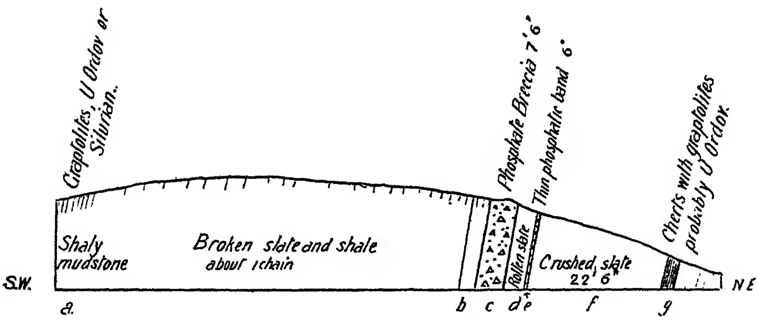


Fig. 4.—Section across outcrop of phosphate breccia.

E. *Concerning the Age of the Diabase and the Cherts.—A Comparative Review.*

These rocks from stratigraphical considerations appear to be the oldest rocks in this region, which necessarily places them low down in the older Palaeozoic series, but on the evidence available in this region alone it would be difficult to assign a definite horizon to them.

The view in this direction, however, is strengthened, and much uncertainty as to age is removed, when a comparative review is made of other closely similar occurrences in the State. Various gaps in the evidence, which make any one area in itself incomplete disappear when all are taken in conjunction. The other areas which call for special consideration in this direction are:—

1. Heathcote.
2. Dolodrook River, near Mount Wellington, Gippsland.

The fossil evidence of the *Dinesus* beds with associated *Protospongia* cherts, at Heathcote, established the age of the rocks as Cambrian.

There would seem to be little doubt that the Howqua rocks are on an extension of the Dolodrook line, where the age is definitely fixed by the tribolite limestone. The absence of this evidence at the Howqua, however, is counterbalanced to some extent by the presence of *Protospongia* cherts and overlying Lower Ordovician rocks, containing such graptolites as *Tetragraptus* and *Didymograptus*. At the Dolodrook, Upper Ordovician rocks come directly in contact with the Cambrian. Again, as an offset against the paucity of direct fossil evidence at the Howqua, we have the very complete lithological resemblances and mineral changes which match the typical Heathcote occurrences. There would seem little doubt,

therefore, that the diabases and cherts of the Howqua belong to the Heathcotian series, and must be regarded as Cambrian. Whether also some of the adjoining sediments are to be included in this series must at present be left an open question.

6.—The Upper Palæozoic Rocks.

The present investigation was principally concerned with the relationships of the older rocks, but some of the later geology is not without interest, and as rocks of this age are found in the northern portion of the area under consideration, where they come into contact with the diabase, a little time was devoted to roughly demarking their boundaries and noting their main features. The rocks of this series fall into the following groups:—

A.—Devonian.

1. Dacite, porphyry,
2. Granodiorite.
3. Diorite.

B.—The Lower Carboniferous.

1. Basal conglomerates.
2. Rhyolite.
3. Conglomerates.
4. Sandstones.
5. Purple shales

1. *Dacite Porphyry.*—This rock covers a considerable tract of country between Mount Timbertop and the Howqua, and extends easterly towards the Buller Creek, where it gives place to Lower Palaeozoic strata. It is also found to the north outside the region of this map on the fall towards Merrijig. Rock of this nature is widely distributed in the King River Valley, as indicated by Kitson.[12] In both localities it underlies the basal conglomerates of the Lower Carboniferous beds, in which pebbles of the porphyry are not uncommon. In the Howqua area this feature was noted in the Timbertop conglomerates. Professor Skeats[5] has referred to the King River porphyry as related to the Dacites. In hand specimens the rock has a general dark colour, on account of a dark, fine-grained base. It inclines to red, where oxidized and weathered. Phenocrysts of felspar and quartz are abundant, the former predominating, and show up on the dark base, imparting a typical porphyritic appearance. Garnets are frequently recognizable. Under the microscope in thin sections chemical alteration in all the specimens examined has proceeded too far for satisfactory determination.

The structure is typically porphyritic, the base is fine grained and felstic, often showing flow phenomena. The phenocrysts in order of abundance would appear to be, felspar, ferromagnesian mineral, quartz and occasional garnets. The felspars are more or less decomposed, but in general the twinning and cleavage can be recognised. There appears to be about an equal amount of repeated and untwinned forms, but undoubted orthoclase has not been recognised for the refractive index is invariably higher than that of the canada balsam.

The quartz is often rounded, cracked and embayed. The ferromagnesian minerals have been almost completely chloritized, but their outlines are marked by black outlines due to iron oxides. Biotite is indicated, and hypersthene and hornblende are also suggested. The amount of ferromagnesian mineral indicates a rock related to the Dacites (Slides 29, 30, and 32.)

2. *Granodiorite.*—This rock is very abundant in the boulders of the Howqua, but it is only found in situ within the area mapped in the extreme north-eastern corner on the slopes of Mount Buller. Its intrusive character is shown by the contact alteration of the adjoining Lower Palaeozoic strata. All the sections prepared were from boulders in the Howqua, as these were the freshest specimens obtainable, and their source was known with fair certainty. The prevailing rock has a typical granitic structure, and is of a grey colour, but very fine grained varieties are not uncommon, showing a tendency to porphyritic structure.

It is worth recording that a small splash of molybdenite was noted in one of the boulders.

Hornblende, biotite and triclinic felspar are readily recognizable in hand specimens. In thin sections, felspars appear to be slightly more abundant than quartz. Twinned and untwinned forms are about equal in amount. The repeated twinning is very minute, with occasional fine cross twinning, suggesting anorthoclase.

Biotite and hornblende, both green in colour, are invariably present, but in varying quantities in the different slides. In the basic segregation patches, the hornblende predominates, and the nature of the rock approaches that of a normal diorite. In general the character of the rock compares closely with that of the normal granodiorites of the State, and its association with the rocks of a dacite type is also similar. This intrusion, therefore, is probably to be correlated with the general and extensive one affecting eastern and south-eastern Australia, and regarded as Lower Devonian in age.

3. *Diorite.*—This rock has not been observed in situ yet, but fresh specimens are abundant in the river gravels, and, judging from the most basic segregation patches in the granodiorite, it is most probably that the diorite is magmatically related to the granodiorite, and is no doubt associated with it in its occurrences, The rock in hand specimens is medium grained, crystalline, of dark colour, showng abundant hornblende and felspar. In thin sections the structure is holocrystalline, inclining to panidiomorphic, but the ferromagnesian minerals are imperfect in this direction. The felspars are most abundant and appear to be almost entirely triclinic. Quartz is rare, being present only as odd grains. Ferromagnesian minerals are abundant, but bulk less than the felspars. They consist of typical green hornblende and greenish brown biotite.

B. *Lower Carboniferous.*

The age of these rocks is determined from the evidence of the fish remains found in the Mansfield area, with which these beds can be seen to be continuous. They form part of an extensive series of sediments extending from Mansfield south-easterly into Gippsland.

1. *Basal Conglomerates.*—These are not largely developed within the area mapped, but small remnants are found directly overlying the dacite porphyry on the slopes between Timbertop and the Howqua, and one small outcrop in the track near the top of Timbertop Gap rests in the decomposed diabasic rocks. It contains pebbles both of this rock and of the porphyry. Quartz and quartzitic rocks are perhaps the most abundant generally, but porphyry, red jasper, and diabase can generally be recognised.

2. *Rhyolite.*—This is a well-defined sheet of variable thickness which at Timbertop amounts to about 600 feet. It generally rests on the conglomerate, but occasionally this bed appears to be absent, and it rests directly on the porphyry, as on the spur east of Blackbird Creek. Upon it is found almost invariably either conglomerate or pebbly sandstone.

The rock is distinct from the porphyry. It is more felsitic, with fewer phenocrysts, which are entirely felspar and quartz. Flow structure is generally apparent. The colour is generally red and the rock is decidedly more siliceous than the porphyry.

Thin sections show it to be typical rhyolite, but the specimens examined are more ferruginous than those of Mount Wellington, and the felspar phenocrysts, all orthoclase, are more abundant than

the quartz. Secondary silicification is apparent in some sections. No ferromagnesian minerals were noted. (Slides 26, 28, and 34.)

3. *Conglomerates.*—This bed often passing into pebbly sandstones generally overlies the rhyolite almost everywhere in this series. It is well developed at Mount Timbertop, where it passes up into the normal sandstone.

4. The sandstones are generally of a coarse texture, often flaggy and micaceous, and with a reddish colour. They form as a rule thick beds which alternate with a purplish to chocolate coloured shale, which sometimes has the appearance of an oxidised ash bed. The shales generally provide good grazing country. The colour, texture and generally low angle of dip of these rocks render them readily distinguishable from the older rocks in the field. Their influence on the topography, too, is distinct.

The alternation of hard and soft beds more or less horizontally disposed gives the hills in general a table topped and ledged character, so well shown in the neighbourhood of Mansfield.

Summary and Conclusions.

The area examined covers about 60 square miles of mountainous country, previously unmapped. It lies about 20 miles to the southeast of Mansfield, and forms a portion of the central highland region of Victoria. Physiographically it consists of an area of high relief in an advanced stage of deep dissection. The original plateau character is almost completely obliterated. Deep valleys with permanent streams separated by steep narrow ridges occupy the whole of the region. Small remnants of an overmantel of flat-lying rhyolite and sediments are preserved, providing a topographic contrast to the outline of the highly folded older rocks.

The area lies in the drainage basin of the Upper Goulburn. and the development of this river system as a whole is intimately connected with interesting tectonic and structural questions.

The main problem dealt with in the area concerns the occurrence of diabasic rocks and cherts closely similar to those of Heathcote, and their relations generally with reference to the Heathcotian problem in Victoria.

The lithological resemblances are most striking, both with regard to the diabase and its alteration products. The cherts occupy a similar relationship, and in each case contain *Protospongia*. Contact alteration features are absent, and the rocks for the most part have the character of altered lavas and tuffs of submarine origin.

The trilobite rocks which at the Dolodrook and Heathcote provide evidence of the Cambrian age, are absent in the Howqua, but the field evidence shows that the diabases and cherts are low down in a series of sediments, in the higher portions of which Lower Ordovician fossils have been discovered.

At Heathcote the succession from Cambrian to Lower Ordovician appears to be conformable, the diabases and cherts being on an undoubted Cambrian horizon. It appears reasonable here to include the similar rocks of the Howqua in the same period.

With regard to the associated Lower Palaeozoic sediments, a lithological and fossil discordance on the western and eastern sides of the main diabase is noted and discussed. Upper Ordovician and possibly Silurian fossils are restricted to a small area on the western side, close to the diabase. The rest of the sediments on this side have so far yielded no fossils. They consist largely of slates, sometimes black, often talcose and chloritic, and usually highly contorted. Chertification is slight. On the eastern side the *Protospongia* cherts appear to be conformably in contact with the diabase. They form a well defined zone, which is followed by a series of alternating sandstones and olive green phyllitic slates so far unfossiliferous over a great range of thickness. Higher in the series, thin bands of black slate carrying Lower Ordovician fossils are interbedded with strata of this type. No Silurian fossils have yet been obtained on this side. Some which are possibly Upper Ordovician occur.

The general structure of the area is somewhat obscure, but a faulted anticline with the Upper Ordovician or Silurian included as a small nipped-in piece, is suggested, as illustrated in the sketch section.

The upper Palaeozoic rocks are briefly referred to:

The rocks of Devonian age are:—

1. Dacite Porphyry.
2. Granodiorite.
3. Diorite.

Those of Lower Carboniferous age are:—

1. Conglomerates.
2. Rhyolite.
3. Pebbly and flaggy sandstones.
4. Purplish shales.

Fig. 1. × 35 diam.

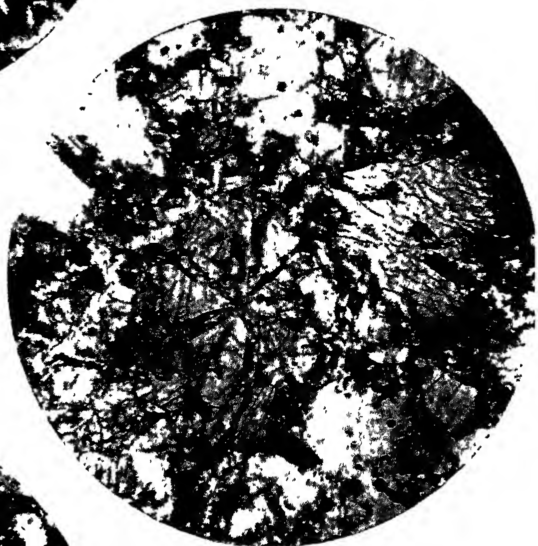


Fig. 2. × 35 diam.

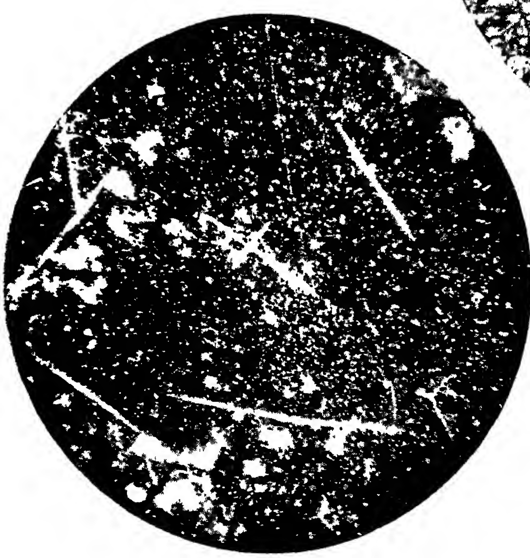


Fig. 3. × 24.5 diam.

Acknowledgements.

I have previously referred to willing help and criticism afforded by Professor Skeats, who has now come to the rescue at the eleventh hour by kindly offering to deal with the petrological description of the more typical forms of diabase. This work was postponed pending the completion of chemical analyses by the author, but the necessity of leaving at short notice for West Africa would have meant leaving this section in a very incomplete form had it not been for this friendly offer. I am also greatly indebted to my father for constant companionship in the field, where the roughness and inaccessibility of the country would have added considerably to the difficulty of the work had it been necessary to do it alone.

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DESCRIPTION OF PLATE V.

Fig. 1.—Rock section, No. 25. Soda-rich diabase from Lick Hole Creek, one mile north of the Governor, and near the south-east end of the main diabase mass. Section × 35 diameters. Polarized light. A large simple twin of albite is seen with smaller quadrate and irregular crystals. The dark areas are principally interlocking fibres of actinolite with augite.

Fig. 2.—Rock section, No. 15. Compact diabase from Four Mile Creek. Section × 35 diameters. Ordinary light. Abundant augite, showing its cleavages with a few radial penetrating felspar laths are seen. Black ilmenite is noticeable, and the clear areas are pale chlorite.

Fig. 3.—Rock section, No. 78. Bedded black chert, Howqua River, on north-east side of main diabase mass. Section × 24.5 diameters, ordinary light. The black background consists mainly of chalcedony. Numerous spicules of *Protospongia* either as straight rods or in triradiate or cruciform arrangements are seen in the field of view.

END OF VOLUME XXXII., PART I

[Published October, 1919].

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. VIII.—*A contribution to the Palaeozoic Geology of Victoria, with special reference to the Districts of Mount Wellington and Nowa Nowa respectively.*

By E. O. TEALE, D.Sc.

(with Plates VIII., IX.).

[Read 14th August, 1919.]

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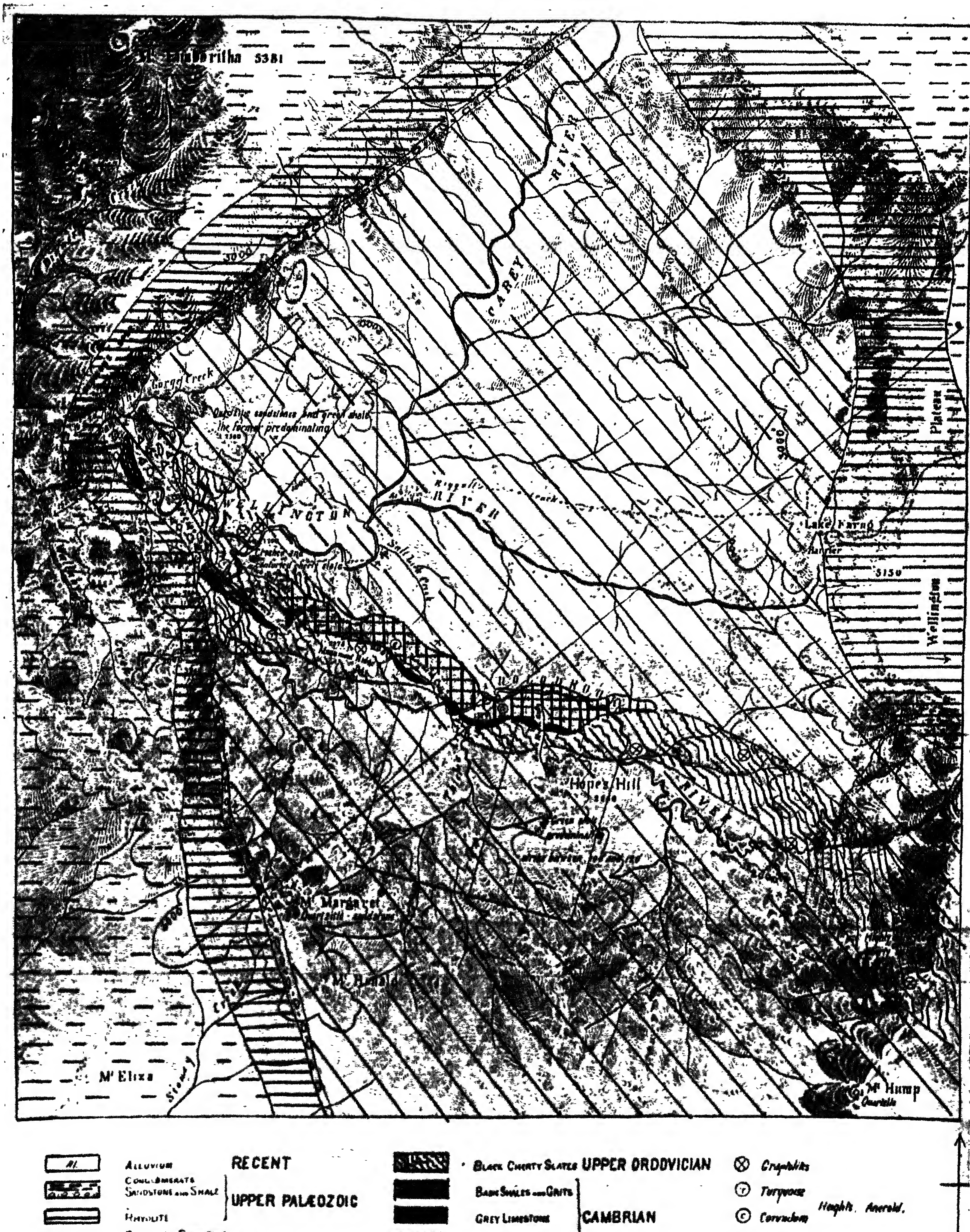


Map of Mt. Wellington Area.

Introduction.

The following observations and conclusions are the result of field work which was started in the vicinity of Mount Wellington, in North Gippsland, about fifteen years ago. It was the existence of a small, imperfectly known mountain lake, close to Mount Wellington, which first attracted the writer to this region. Lake Karng, as it has been named, had been visited by the late Dr. Howitt about fourteen years previously, but the question of its origin was not definitely settled. Of the two views discussed by Howitt (1 and 2), namely, glacial and landslip origin, the glacial was most favoured.

No other scientific observer had visited the lake until the writer's examination in December, 1904. A report of the excursion appeared in the "Victorian Naturalist," 1905 (11). The landslip origin of the barrier which forms the lake is there upheld, and several subsequent visits by the writer have greatly strengthened this conviction.

Incidentally, the first excursion showed that the whole region was full of interest, both geologically and physiographically, and during the years 1904 to 1908 (11, 12, 13), four short vacation expeditions were made into various parts of this district. The most important result of this preliminary work was to show that to the west of Mount Wellington there was an extensive and complex inlier of Lower Palaeozoic rocks in an area previously regarded as Upper Devonian. In this region, along the Wellington and Dolodrook Rivers, extensive outcrops of black cherty slates were discovered, yielding abundant and beautifully preserved Upper Ordovician graptolites. Serpentine containing Corundum and Chromite was also found to occur along a belt within the Ordovician area, but its age and relationship to the surrounding rocks had not yet been worked out. Several outcrops of grey crystalline limestone intimately associated with the slates and serpentine were next discovered, and these proved later to be some of the most important and interesting rocks of the district. At first a small brachiopod was the only fossil obtained, which Mr. Chapman regarded as a Silurian form, but later another outcrop of limestone yielded abundant trilobites, which Mr. Chapman confidently recognised as Upper Cambrian (13 and 15). This came as a surprise, for though the field observations were limited, they had not suggested the marked stratigraphical break which the palaeontological evidence now demanded. Shortly previously to this discovery, Mr. E. J. Dunn (16), late Director of the Geological Survey, in company with

Professor E. W. Skeats, made a flying visit to this region, spending only about four days there. Mr. Dunn's attentions were specially directed to the examination of the Serpentine, with the associated occurrence of the Corundum and Chromite, but the observations of both these geologists on the relations of the limestone to the surrounding rocks, though hurried, led them also to receive with some surprise the possibility of their being regarded as Cambrian.

A few years previously, in 1902, Professor Gregory, from a study of several Lower Palaeozoic areas in Victoria, but particularly in the vicinity of Heathcote, claimed that a Pre-Ordovician series of probable Cambrian age existed; and to which he gave the name Heathcotian. Professor Gregory's conclusion was not, however, accepted with full confidence by all the Victorian geologists, and later, Professor Skeats (18) examined carefully the Heathcote rocks, and in 1908 published a very comprehensive review of the situation, concluding that the evidence in favour of a Pre-Ordovician series at Heathcote was not conclusive. He therefore for the time being favoured the inclusion of the doubtful rocks in the basal Ordovician.

The Cambrian problem in the Wellington district was therefore of more than local interest since the existing knowledge concerning the occurrence of Cambrian generally in Victoria was in an unsatisfactory state. It was clearly the chief among many interesting and important questions awaiting solution in this region.

At this stage in May, 1908, the writer's departure to undertake geological exploration in Africa under the direction of the Imperial Institute, postponed indefinitely these interesting researches.

A paper was therefore written, embodying the conclusions arrived at, and stating also the more important unsolved problems (13).

Early in 1915, while in Melbourne, on a short holiday from Africa, the effect of the war led to the suspension of the African Exploration, and it was suggested by Professor Skeats and Dr. Summers that I should resume in the meantime the Wellington researches. The University offered encouragement and assistance in the form of a Government Research Scholarship, and the opportunity, therefore, to renew the work was gladly availed of.

The foremost aim of the expedition was to endeavour by careful survey to map and work out the relations of the various limestone outcrops to one another, and to the surrounding rocks. It was soon found, however, that the work grew in scope, for the mapping

showed a succession of inliers ranging from Cambrian to Silurian, surrounded by a ring of Upper Palaeozoic sediments with associated acid and basic lava flows. Important broad structural and tectonic considerations involving palaeozoic geology generally therefore, became involved.

On the first expedition of renewed exploration in April, 1915, I was accompanied by my father, Mr. A. O. Thiele, who had been a constant helper throughout the numerous field trips to this area. Mr. Herman, Director of the Geological Survey, also kindly arranged for Mr. J. Caldwell, one of the officers of the Survey, to join the party as a field assistant, and I am greatly indebted to the willing and able help rendered by both these persons.

Various unavoidable difficulties, due partly to the season and partly to the rough nature of the country, prevented the completion of the work before the wet season set in, and as the district was unsuitable for winter field work, it was decided to choose another region in the meantime, offering unsolved problems likely to bear in some way with those of the Wellington region.

The district, therefore, between Nowa Nowa at the head of Lake Tyers and Buchan, was chosen, for it included two occurrences believed by Mr. Dunn to be of Heathcotian age, one in Boggy Creek and the other in the Tara Range (19), south-east from Buchan.

In Boggy Creek, just north of Nowa Nowa, Mr. Dunn had stated that diabases associated with cherts occurred and in the Mount Tara goldfields he had recognised cherts. Both these occurrences had been included in the Heathcotian on purely lithological grounds, but the relationship to the surrounding rocks had not been worked out. This district further offered an opportunity of studying a portion of the important belt of igneous rocks known as the "Snowy River Porphyries," thus affording scope to discuss the Palaeozoic volcanic history generally, of which the Wellington series form an important chapter.

These various journeys through Gippsland provided also some interesting physiographical studies, so that the extent of the work has gradually grown until it includes a number of distinct problems which will now be considered in turn.

WELLINGTON DISTRICT.

The Palaeozoic Geology.—The Wellington region forms part of one of the important major tectonic and structural zones of Victoria, which may be conveniently termed the Mansfield-Welling-

ton zone. This belt bears the record of a long succession of tectonic volcanic and sedimentary events ranging practically throughout the Palaeozoic period, starting with Cambrian and closing with Lower Carboniferous. There are probably three distinct periods of igneous activity represented, namely, Cambrian, Lower Devonian and Lower Carboniferous. A succession of powerful fold and fault movements along a line varying between N.N.W. and N.W. acting at intervals throughout this period, has impressed especially in the older formation, some marked structural features in the form of intense folding, crumpling and crushing. A general parallelism in strike as a rule exists between the different formations, and the evidence of unconformities has to be considered very carefully. The problems of any portion of this extensive and mountainous belt should take note of the general features of the whole area as far as possible, but, unfortunately, much of the region is still very imperfectly known, and some of it has never been examined geologically. The Wellington area forms the southern end of the belt, and rises abruptly from the northern edge of the great Gippsland Plains, a little to the north of Heyfield, and forms a part of the great Central Highlands of Victoria.

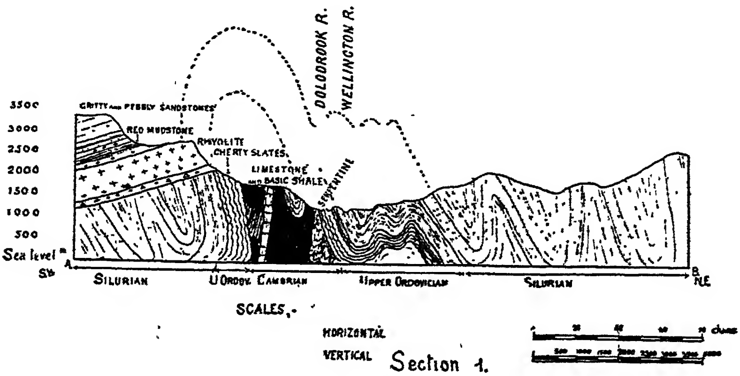
The Mansfield region lies near the northern end, across the Main Divide, not far from the border of the Highlands with the northern plains. The length of the whole belt is about 100 miles, with a width up to about 40. Much of it is covered by Upper Palaeozoic sediments and igneous rock, but extensive denudation has in places stripped off this covering, and laid bare the older rocks, notably near Mansfield, in the Howqua Valley, and also in the Wellington and Dolodrook Rivers. The need for further work in the first and second localities will be explained later. The particular features of the Palaeozoic rocks of the Wellington area will now be taken in order and some reference made to related occurrences elsewhere in Victoria.

Pre-Ordovician Series (Heathcotian).—Under this division there are three distinct groups of rocks:—

(a) Serpentine	Pre-Upper Cambrian.
(b) Trilobite Limestone	Upper Cambrian
(c) Garvey Gully series of Sediments	

The general occurrence of this series is shown on the map of the Wellington region, and the accompanying Sections (Map No. 1 and Sections 1 and 2). It will be seen that the rocks of this series occur as a long, narrow curved inlier striking generally in a northwesterly direction, which is the grain or trend of the whole structure

of the area. A narrow, incomplete ring of black cherty graptolite slates of Upper Ordovician age almost surrounds the inlier, but on the northern side along a portion of the contact the Silurian sediments rest directly against the Serpentine. The whole series is intensely crushed and contorted, and so are the Upper Ordovician

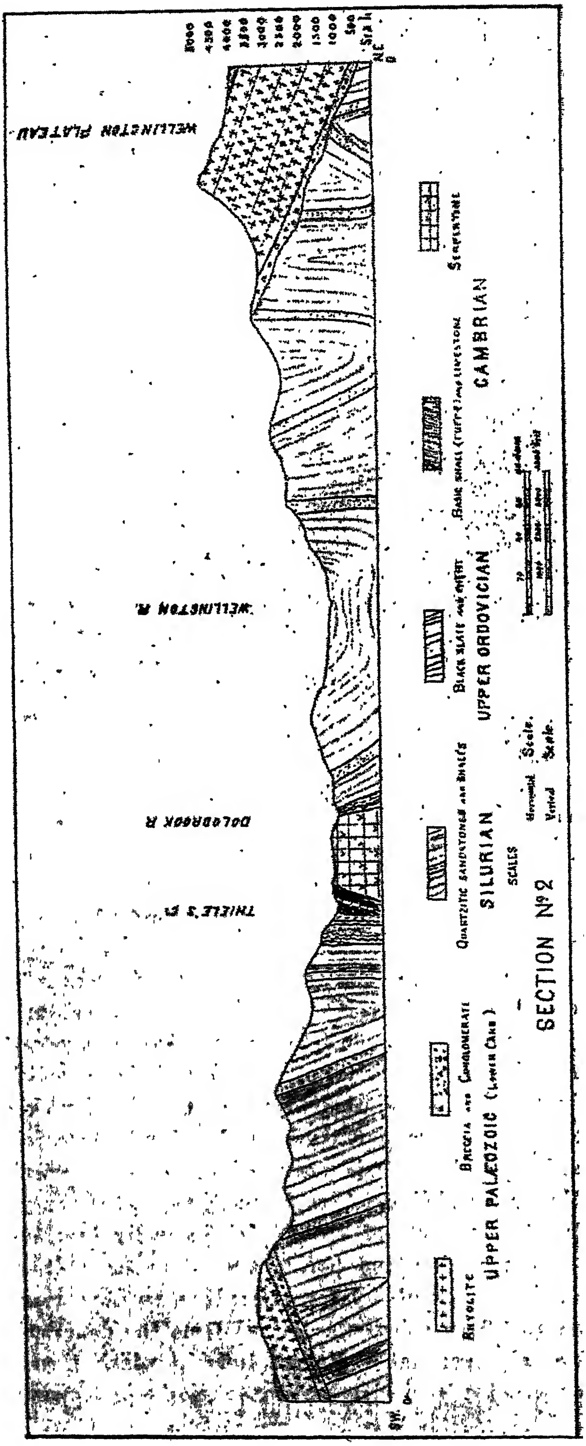


Section 1.

Section showing relation of Cambrian Inlier to surrounding Rocks Dolodrook River

rocks. As all the successive formations have been subjected to periods of folding and compression along a north-westerly direction, they have a similar strike, and small vertical sections of contacts do not yield conclusive evidence of unconformity. The mapping, however, of the boundaries gives more satisfactory information in this direction, and everywhere the lithological and palaeontological break is quite sudden.

The Serpentine.—The extent and general features of this rock with its associated minerals, Chromite and Corundum, were described in a previous paper (13), but the age and relationship to the surrounding rocks had not been definitely established. The Serpentine was then regarded by me as the oldest rock occurring in this region, and was put down as Pre-Upper Ordovician. This view is still upheld, but it is now possible to further restrict its age to Pre-Upper Cambrian. The Serpentine was shown previously (13) to be of the nature of an altered intrusive rock, originating from both pyroxenites and peridotites. Various rocks are found directly in contact with it, for example, serpentinous grits, conglomerate and finer sediments derived from the denudation of the serpentine, also associated diabase tuffs in which there are definitely interbedded lenticular limestone deposits of Upper Cambrian


WELLINGTON PLATEAU
WELLINGTON R.
DOLODROOK R
THIELE'S CK
SW.
NE
RHYOLITE
BRECCIA AND CONGLOMERATE
QUARTZITIC SANDSTONES AND SHALES
BLACK SLATE AND CHERT
SERPENTINE
UPPER PALÆOZOIC (LOWER CARB.)
SILURIAN
UPPER ORDOVICIAN
CAMBRIAN
SCALES
Horizontal Scale.
Vertical Scale.
SECTION No 2

age; elsewhere Upper Ordovician slate or Silurian sandstone and shale directly overlie the Serpentine. Nowhere has there been observed any rock showing contact alteration. The conclusion, therefore, is clear that not only is the Serpentine the oldest rock but there is a stratigraphical break between it and the next oldest rock, the Upper Cambrian, sufficient to allow of considerable denudation previous to the deposition of the Upper Cambrian. The intense shearing and foliated character of much of the Serpentine has been previously referred to (13). It is generally recognised that a certain amount of such structure frequently found in Serpentine is due to intense expansional forces generated by the increase in volume, which accompanies the mineralogical change from pyroxene and olivine into Serpentine. Additional stresses, however, of an intense character due to general compressional earth movements have further deformed these rocks, and have largely contributed to their schistose character.

A very useful and comprehensive summary of the state of our knowledge concerning the Heathcotian Series is given by Professor Skeats in the "Volcanic Rocks of Victoria" (18). It includes references to various Serpentines and associated rocks in Victoria, some of which have been doubtfully referred to by various geologists as Pre-Ordovician. Further interesting information and statements concerning Cambrian occurrences generally in Australia are discussed by Professors David and Skeats in the Federal Handbook, in the section dealing with the geology of the Commonwealth (20). Serpentine has been shown to occur in a number of widely-separated localities frequently associated with cherty and diabasic rocks, notably at Waratah Bay, near Casterton and the Limestone River, Benambra. These rocks have been doubtfully included by some authorities in the Pre-Ordovician Series, but though little is known concerning the relationship to the surrounding rocks, the definite fixing of the age of the Wellington Serpentine adds a little more weight to the conjecture that these other occurrences may be correlated with the Pre-Ordovician.

It is interesting to note as previously referred to by Professor Skeats (18) that near Heathcote the diabase at its margin passes into a rock allied to Serpentine, known as Selwynite, containing chromite and corundum, an association also found in the Wellington area.

The Garvey Gully Series.—These rocks were recognised in part in my previous paper (13), under the heading of "Sediments composed largely of Serpentine Detritus, and were doubtfully in-

cluded in the Upper Ordovician. A more extended examination, however, has shown that they are distinct lithologically from the black slates; the junction is always a sharp one, and further the limestone deposits which have yielded definite Cambrian fossils are interbedded with them. Chemically, these rocks are distinct from the adjacent cherty graptolitic slates. Their analysis shows a low silica percentage and relatively high iron, lime and magnesia content. The soil, therefore, derived from their weathering is of a noticeable red colour and clayey character, supporting a richer growth of grass and other vegetation than the rather stony and sterile soil of the slates. The belt is further marked by a rather striking feature of the weathering of some of the fine grained sediments, which petrological examination proves to be tuffaceous. These rocks weather into striking elongate spheroids with a succession of spheroidal shells similar to the well-known structure of partly decomposed basalt and other igneous rocks. Their field occurrence and petrological examination, however, leave no doubt as to their sedimentary origin.

There are two separate occurrences of this series, both of limited extent. The largest and most important is a long narrow belt along the Dolodrook Valley. It starts about a quarter of a mile north-west of Garvey's hut, and extends south-easterly on the southern side of the Serpentine as far as Roan Horse Gully, a distance of three and a half miles. The greatest width is never more than a few chains. The other occurrence is a small outcrop of highly contorted basic sediments exposed in the bed of the Wellington River, roughly on the line of strike, about a mile and a quarter north-west from the termination of the first-named inlier.

At its north-western extremity, the Dolodrook inlier passes out of sight under the Upper Palaeozoic rocks, but along its southern or south-western boundary it is directly in contact with the Upper Ordovician slates. The character of the sediments varies from coarse serpentinous conglomerate through grits to fine greenish diabasic tuffs. Several sections merit special attention.

Locality A, (Dolodrook River).—This position is shown on the map extending from the junction of the Black-Soil Gully, in a south-westerly direction, for about twenty chains. The succession and relationship are represented in Section No. 1. At the junction of Black-Soil Gully with the Dolodrook, there is a small inlier of Serpentine with contorted black cherty slates in contact on the north side. The junction appears to be a fault, and obscure but recognisable Upper Ordovician graptolites can be traced in the cherts almost

up to the junction. Following the river bed upstream, the Serpentine about one chain in width passed serpentinous and ferruginous shale of the Garvey Gully type, highly ferruginous here on account of weathering. The rock continues for about eight chains, when a hard cherty band of contorted slates is encountered. It is about two chains wide and definitely Upper Ordovician, from which characteristic graptolites have been obtained. At first sight, the band has the appearance of being interbedded with the Cambrian sediments, but palaeontological evidence supported by petrological differences and comparison with similar small outliers of Upper Ordovician in the vicinity, shows that the occurrence is due to intense folding which has nipped portions of the overlying Ordovician into the Cambrian. Continuing with the section, the cherts are followed again by a belt of about 10 chains of typical greenish basic tuffs with interbedded Cambrian limestone about one chain wide and beyond this to the south-west, these rocks are bounded by a belt of contorted Upper Ordovician cherts.

The contact between the two series is shown in a small gully which enters the Dolodrook at the limestone outcrop. It is situated about five and a half chains from the junction in a south-west direction. The passage from basic tuffs to cherty slates is sharp, with about two feet of gossany material in between, probably occupying a fault. The rocks are highly inclined and disturbed on either side.

A chemical analysis of the tuff is appended, showing its basic character.

	I.		II.
SiO_2	50.09		48.11
Al_2O_3	12.69		13.30
Fe_2O_3	5.30		3.70
FeO	12.01		8.10
TiO_2	2.12	MnO	1.43
CaO	5.08		8.48
MgO	5.60		9.51
H_2O-	0.40	Loss on Ignition	4.21
H_2O+	2.72		
Na_2O	2.54		1.96
K_2O	1.32		1.57
CO_2	0.80		—
	100.67		100.37
S.G.	2.86		

(I.) Green banded tuff—Garvey Gully series Dolodrook River (Teale.)

((II.) Purple and green tuff between Pen-Maen-Melyn and Pen-Maen-Foel, South Wales, Cambrian, (Wilson), British Petrography, Teall, page 223.

The principal differences to be noted in comparing the Dolodrook tuff with the Cambrian one of South Wales are the greater percentage of iron and smaller amount of lime and magnesia present in the former. No other analyses have yet been made of similar rocks of supposed Heathcotian age in Victoria.

Thin sections of the fine grained tuff (No. 44), from the Dolodrook, show a banded and somewhat schistose structure, with numerous small sub-prismatic and irregular grains of basic plagioclase felspar, many of which are orientated with their longer axes parallel with the planes of schistosity, but many also lie at any angle, frequently across the planes of foliation. Much chloritic and some serpentinous material is present between the felspar grains, but no fresh pyroxenes were distinguished. Magnetite is abundant, and several small grains of quartz were noted. The fragmental structure, together with the chemical and mineralogical composition seems to indicate the nature of an altered subaqueous diabase tuff.

The secondary silicification, which is one of the marked features of the diabase tuffs and allied rocks at Heathcote, is absent.

Locality B.—The next section of importance is about two and a half miles in a south-easterly direction, at the junction of Thiele's Creek with the Dolodrook. Here within a relatively small area there are good exposures of the Serpentine, the basic sediments with interbedded limestone, the Upper Ordovician graptolite bearing slates; and the Silurian sandstones and shales (Map 2).

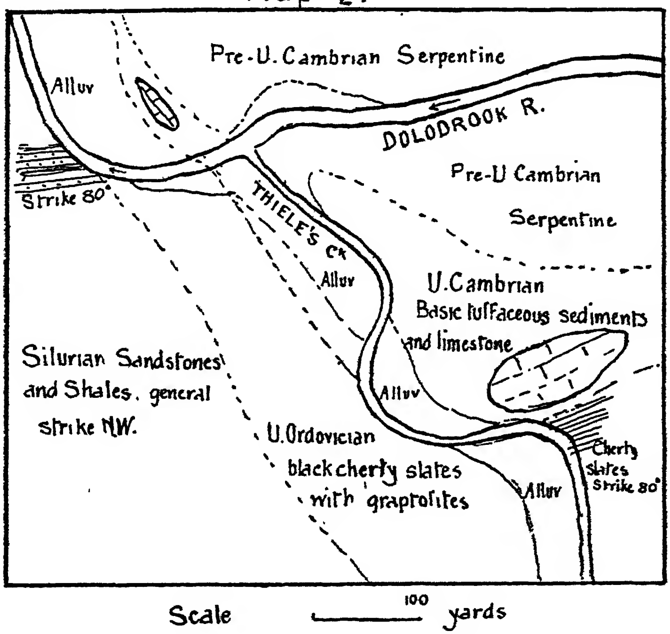
The actual contact of the Cambrian sediments and the Serpentine is shown in the bed of the Dolodrook River, at Thiele's Creek Junction. Here the sediments are of the nature of serpentinous and chloritic conglomerates, grits and finer bands.

A section of this is given by Mr. Dunn (16), who describes the rocks as post-Ordovician, on account of the presence of dense darker rock fragments, which he regarded as Ordovician slate, but which microscopic evidence shows to be a basic igneous rock. The fine dark bands described by Mr. Dunn as slate, prove to be tuffaceous, and similar in character with the basic sediments associated with the Cambrian limestone in every case.

In this vicinity there are two limestone outcrops associated with the basic sediments. Additional thin sections of both the coarse and fine material indicate their tuffaceous character, and support the view also that they belong to the Garvey Gully Series.

The contact and section generally are important, as they show clearly that the Serpentine is a pre-Upper Cambrian rock, the denudation of which in part contributed to the Cambrian sediments.

Map 2.



The remaining portion, consisting largely of diabasic pyroclastic material, indicates an Upper Cambrian volcanic phase.

This section shows also an interesting structural twist in the strike, post-Silurian in age, for the whole series, including the enveloping Ordovician and Silurian rocks, are locally bent round from a north-west strike to one varying between 80° and 100°. This continues for more than a mile easterly, the strike then gradually swinging back to a more normal north-west direction.

Locality C. (Roan Horse Gully).—A traverse from a few chains on the north side of the Dolodrook, opposite the Roan Horse Gully junction, in a S.S.W. direction, across the Dolodrook, and along the bed of Roan Horse Gully, shows well the relative position of the various rocks, and illustrates the typical structure of the inlier.

The limestone is again associated with the same basic sediments, which rest against the south side of the Serpentine. The envelop-

ing Upper Ordovician rocks are found as a very thin belt on the north side of the Serpentine, and repeated just to the south of the limestone. All the strata are highly inclined, being almost vertical, but an overthrust from the north, or north-east, causing a fault in the vicinity of the Ordovician contact, has placed the limestone locally above the graptolite slate, as shown in the sketch section, No. 3. This movement is probably to be correlated with the general overthrust of post-Silurian date, affecting a considerable part of the Dolodrook area, for a fine example of overfolding of the Silurian rock is shown in the Dolodrook, about one mile and a quarter in a straight line below Thiele's Creek junction (Photo. 2).

The Silurian sandstones and shales outcrop at each end of the section forming the next enveloping zone of the complex inlier. The general ge-anticlinal structure is therefore complete along this line.

The Dolodrook Limestones.—These form one of the most important series, for they have provided the definite palaeontological evidence without which it would have been impossible to discover the complete key to the structure of this region.

Previous to resuming the field work in this region, the fossils, chiefly trilobites which Mr. Chapman had definitely concluded to be Cambrian, came from the limestone outcrop No. 1, at the north-west end of the belt.

The first fossil obtained in the district from the limestone, originally regarded by Mr. Chapman as Silurian, came from Roan Horse Gully outcrop, about three and a-half miles to the south-east, but no trilobites had yet been found in this occurrence. The recent field work, however, has been successful in discovering similar trilobites in four separate outcrops, including the Roan Horse Gully limestone, and the mapping generally shows clearly that all the limestone outcrops, of which there are nine, belong to the same series. The additional fossils obtained, Mr. Chapman states, give further convincing evidence of the Cambrian age, and his supplementary palaeontological description will be given later.

Upper Cambrian Fossils.—The following are the fossils described by Mr. Chapman (15) from the Dolodrook :—

Plantae—

Class, Algae. Girvanella Sp.

Animalia—

Class Crinoidea.

Crinoid stems, joints and ossicles.

Class Brachiopoda.
Lingulella.
Orthis (Plectorthis) platystrophioides.
(Originally confused with Platystrophia biforata.)
Class Gasteropoda.
Scenella tenuistriata, Chapman.
Related to Stenotheca—Cambrian of South Australia.
Class Crustacea, Sub. Class Trilobita.
Agnostus australiensis, Chapman.
Ptychoparia thielei, Chapman.
Ptychoparia minima, Chapman.
Crepicephalus etheridgei, Chapman.

The limestone has a pleasing grey colour, is crystalline, and, when polished, would make an attractive ornamental stone, but in its present inaccessible position there is no immediate prospect of it being available for use. No quantitative analysis of its composition has been made, but a qualitative test showed that it was relatively pure, with only a small percentage of magnesium carbonate. All the outcrops are of lenticular character and small extent, the two largest being No. 1 Dolodrook, and that at Roan Horse Gully. The latter can be traced along the strike for about three hundred yards, and shows a good face towards Roan Horse Gully of about a chain in width.

Upper Ordovician.—These rocks, consisting of black slates, with highly cherty bands frequently intensely contorted, have been referred to in a previous paper (13), but their extent and relationship to the other rocks in the vicinity had not been fully traced. It had been recognised in general that they wrapped round the central inlier of Serpentine and associated rocks, but the outer boundary had not been followed. The result of additional field work makes it now possible to indicate these features on the map presented; showing that the Ordovician rocks are in turn enveloped by an outer ring of later sediments, with a distinct lithological and palaeontological break. The slates are everywhere readily distinguished in the field from the less indurated shales and sandstones of the next series. Graptolites are abundant throughout even in the most highly cherty representatives, but naturally the best preserved specimens are obtained from the less altered bands. The forms represented are uniformly Upper Ordovician types. The first graptolites were obtained by the writer in 1905, and were described by the late Dr. T. S. Hall (14). Since then other forms have been

collected from various parts of this area, and numerous other collections have been made by various members of the geological survey throughout Eastern Victoria.

Of these occurrences, the best collections have come from (1) Matlock, (2) the Thomson-Jordan Valley, (3) the Black River Belt, and (4) the Wellington area. These four localities consist of parallel strips of Upper Ordovician rock, separated by belts of Silurian sandstone and shale. The fossils show that these outcrops, if not identical in horizon, are at any rate, very closely allied; and owe their reappearance to successive intense folding along lines of N.N.W. axes, resulting also in the folding of the overlying Silurian rocks in a similar way. Subsequent denudation during the present cycle of erosion has exposed some Ordovician as inliers. They are generally narrow, elliptical belts, conforming to the general strike, but disappearing along the strike under the Silurian, often to reappear, however, at varying intervals along this line. This is due mainly to a very general development of pitch, sometimes north and sometimes south. This structure, common throughout the older rocks of Victoria, has been clearly brought out in the Wood's Point and Walhalla district by the excellent field work of Mr. O. A. L. Whitelaw and Mr. W. Baragwanath respectively.

Up to the present no definite graptolite zones have been recognised in the Upper Ordovician in Victoria. It is probable that the vertical range in the Upper Ordovician is not so great, but it is likely that systematc work would yield some definite results in favourable areas.

The following is the complete list of graptolites recorded from the Wellington region :—

Diplograptus foliaceus, Murchison.
Diplograptus thielei, T. S. Hall.
Diplograptus (Orthograptus) quadrimucronatus, J. Hall.
Diplograptus (Orthograptus) calcaratus, Lapworth.
Leptograptus flaccidus, J. Hall.
Climacograptus wellingtonensis, T. S. Hall.
Climacograptus bicornis, J. Hall.
Climacograptus bicornis, var. tridentatus, Lapworth.
Climacograptus tubuliferus, Lapworth.
Dicellograptus elegans, Carruthers.
Dicellograptus morrisi, Hopkins.
Dicellograptus gurleyi, Lapworth.
Cryptograptus tricornis, Carruthers.

Dicranograptus nicholsoni, Hopkinson.
Dicranograptus hians, T. S. Hall.
Nemagraptus gracilis, J. Hall.
Lasiograptus margaritatus, T. S. Hall.

Most of the above species are widespread and abundant in their occurrence throughout the area, but Orthograptus calcaratus has only been found at one spot in the north-western extremity of the Ordovician, marked G, where it is associated with abundant Climacograptus bicornis and another rare form, C. tridentatus. The last-named species was also found at another locality, marked $G._2$.

Splendidly preserved specimens were obtained, and it is the first undoubted record for Victoria, a doubtful instance has been recorded from Cravensville.

Nemagraptus gracilis has only been found in Roan Horse Gully.

Dicellograptus gurleyi is also rare, and has only been recorded from the Wellington area.

See comparative table, showing general record of Ordovician graptolites in Victoria.

It is interesting to note that a small amount of turquoise was observed in several places, chiefly as very thin veinlets in the joints of the cherty rocks and, occasionally, also associated with white quartz.

The mineral is evidently widespread in its occurrence in the Upper Ordovician rocks in Victoria. The best known localities are Ryan's Creek, Myrrhee (31), and Mt. Avis, Edi, King Valley, Mr. Caldwell tells me that he found it in black slate on the Black River, and I found it myself in light-coloured chert in the Tara Range.

A certain amount of white powdery phosphatic material also occurs irregularly distributed along joints and fractures. One sample of altered siliceous rock yielded an analysis 8% of P_2O_5.

Some phosphatic deposits of promise from an economic standpoint occur in the vicinity of Mansfield. They are associated with Ordovician rocks, but their true relation is still the subject of controversy.

The cherty nature of the Ordovician rocks of the Wellington district is a noteworthy feature. The prevailing colour is black, and the most completely altered bands are of the nature of lydianite or black jasper. All grades of silicification occur, and though in general the cherts run in bands with intervening belts of more normal slate, instances are common showing slightly chertified slate

a few inches wide between beds of jasper. There has clearly been a selective action in the process of silicification, probably controlled mainly by primary differences in composition existing in the original strata. Thin sections, however, of the slates and cherts have so far not revealed what these differences were.

The alteration is not attributable to the direct contact action of igneous intrusion, but would appear to be explained by a selective metasomatic replacement due to aqueous solutions permeating the rock.

Instances of this type of chertification are found throughout the Palaeozoic rocks. It is natural, therefore, to find cherts of very different ages resembling each other somewhat closely, and this has led to considerable confusion on account of some geologists having correlated numerous cherty outcrops with the "Heathcotian" on purely lithological grounds.

Professor Skeats (18) has discussed the origin and occurrence of the cherts of the Heathcote area, and has shown that they are largely due to metasomatic replacement of diabase and diabase tuffs. The age is left an open question, but their inclusion in the basal portion of the Ordovician was favoured on the then known palaeontological evidence.

Dr. Summers (21) has described cherts and associated rocks at Tatong, where they are interbedded with fairly normal sediments, which he regards as Upper Ordovician.

In the Wellington area and in the Tara Range, near Buchan, I have found Upper Ordovician graptolites actually in the cherts. It is therefore clear, as Dr. Summers points out, that the occurrence of cherts as characteristic of the Heathcotian Series loses its significance.

Up to the present no radiolaria have been noted in thin sections of the Wellington cherts which have been examined.

Reviewing the important structural points brought out by a study of the Lower Palaeozoic geology of the Wellington area, it is clear that the axis of this complex inlier marks an important structural line, the direction of which is parallel with the main Palaeozoic trend lines, along which a succession of important tectonic movements have been renewed many times. We therefore find the zonal arrangement of successive formations bearing in a prevailing N.N.W. to N.W. direction very marked, exposing in this case within a remarkably small area, narrow, parallel but unconformable belts from Cambrian to Silurian.

With this in mind, it is natural to look expectantly along the continuation of the strike of this belt.

Upper Ordovician Graptolites.

	Mt Wellington District. EDT	Turquoise Mine, Ryan's Ck, Myrrhee. BMH	" " Mt Avis, EDJ. BMH	North slope Mt Easton, 3 miles from Thomson-Jordan Junc.	Dingo Ck, 290 2 mls Thomson-Jordan Junc. W.Bro	Main Divide between Mt Selma and Spring Hill. OALW	Black R., near junction with Ten Mile Ck.	Two miles NW of Mt Easton.	Three quarters of a mile NE of Mt Easton.	Matlock, 1½ mls SW Kelly's Hill. EDT and Geol Surv	Sandy's Creek Mitchell R	Cravensville.	Dark R.	Tungamah.	Snowy R, Mt Deddick.	Accommodation Ck. Deddick.	Walwa Ck.	Wombat Ck.	Mt Deddick (river pebbles)	Cabandandra.	Thoona.	McLaughlan's Ck.	Two miles west of Myrtleford. EJD	Kerrie ° U Ordovician	Myrtleford, 10 ch. NE Allot 2 (W Clemens)	Nona Nona. OALW	Tara Range. EDT	Parish of Newham, Sec VA. EWS + HSS	S. of U Macedon, Loc 57.	Emu Creek, Allot 48A, Kerrie	Kensington. OALW	Jordan R, 2½ miles above Jericho. OALW
Diplograptus sp.	⊕	⊕	⊕		⊕	⊕	⊕																					⊕	⊕		⊕	
D. cf tamariscus, Nicholson										+																						
D. foliaceus Murchison	+			+	+		?		+	+		+				+			+		?									+		
D. thielei, T.S. Hall.	+																															
D. carnei, T.S. Hall.								+									+	?				?										
D. ingens, T.S. Hall									+																							
D. pristis																		?														
D. cf aculeatus, Lapworth									+																							
D (Orthograptus) quadrimucronatus, J Hall	+								+																							
D . angustifolius, J Hall.																										+						
D . tardus, T.S. Hall.																																+
D . calcaratus, Lapworth.	+															+																+
Leptograptus sp																															⊕	
L. flaccidus, J. Hall.	+							+	+																							
Climacograptus sp.			⊕	⊕	⊕		⊕	⊕																⊕		⊕	⊕					
C. wellingtonensis, T.S. Hall	+																															
C. bicornis, J Hall.	+			+					+			+							+													+
C. bicornis, var peltifer, Lapworth.																																+
C. tridentatus, Lapworth.	+											?																				
C. baragwanathi, T.S. Hall.									+																							
C. hastatus, T.S. Hall.										+																						
C. tubuliferus, Lapworth.	+			+						+							+			?												
C. cf. innotatus, Nicholson.										+																						
C. caudatus, Lapworth.																+																
C. mensorius, T.S. Hall.								+																								
Dicellograptus sp								⊕				⊕					⊕		⊕				⊕								⊕	
D. affinis, T.S. Hall.				+	+					+									+													
D. elegans, Carruthers.	+			+					+									+		?										+		+
D: morrisi, Hopkinson.	+									+										+												
D. gurleyi, Lapworth	+																															
D. cf anceps.																		+				?										
D. sextans, J Hall.																																+
D. complanatus, Lapworth var. ornatus, Ells and Wood								+																								
D. aff. forchammeri, Geinitz.					+																											
Cryptograptus tricornis, Carruthers.	+								+							+																+
Dicranograptus sp.							⊕																								?	
D. nicholsoni, Hopkinson.	+								+																							
D. hians, T.S. Hall.	+								+							+																
D. ramosus, J. Hall.									+		+			+	+																	+
D. var. semispinifer T.S. Hall.																?																
D. var. longicaudis T.S. H.																										?						+
D furcatus, J. Hall.																																+
Nemagraptus gracilis.	+																															
Lasiograptus margaritatus, T.S.H.	+			⊕				+	+																							
Glossograptus sp.	⊕		⊕	⊕					⊕																		⊕				⊕	
G. fergusoni, T.S. Hall				+																												
G. hermani, T.S. Hall.		+	+								+	+	+	+							?					+						?
Clathrograptus geinitzianus, J. Hall.																										+						
Dendrograptus sp.		⊕							⊕	?																						
Didymograptus cf caduceus, Salter.			⊕		⊕									+												+		?				
D. ovatus, T.S. Hall.											+																					
Dichograptus, sp			⊕																						⊕	⊕						

Note — ⊕ indicates that the genus only has been recorded.

It may be of some significance, therefore, that we find in this line other complex Lower Palaeozoic inliers, whose structural details and relationships are still a subject of controversy, and provide promising scope for further work.

The phosphatic deposits at Flannery's, near Mansfield, and the associated sedimentary rocks form one of the most interesting inliers in question.

Some very fragmentary fossils were obtained some years ago from the phosphatic material, consisting chiefly of Salterella, and obscure trilobite remains. The fossils were very unsatisfactory, but were regarded by Professor Gregory as probably Cambrian. Professor Skeats and Dr. Summers have obtained both Upper and Lower Ordovician, and Mr. A. M. Howitt Lower Ordovician graptolites in such close proximity to the spot from which the trilobite remains were found that the geology is clearly complex, and the results of more detailed work should be of considerable interest.

Another area requiring further attention is in the Upper Howqua Valley, at such a position that the extension of the Cambrian axis of the Wellington region might be expected to appear.

Mr. A. M. Howitt (22) made a flying visit to this region about eleven years ago, and recorded the occurrence of cherts, which were regarded as Cambrian, phosphate rock, amphibolites and serpentine of undetermined age, also Silurian slates and sandstones.

The relationship of these rocks has recently been discussed by the author in the Proc. Roy. Soc., Vic.

Silurian.—The rocks of this series consist chiefly of alternating quartzitic sandstones and greenish sandy shales. Some of the latter have a marked rubbly to splintery mode of weathering, and by oxidation are frequently rusty brown near the surface. They dip at high angles, and have been folded along numerous axial lines in a general N.N.W. to N.W. direction. Though they have been subjected to much folding and even overfolding, as shown in the Dolodrook, below Thiele's Creek junction (Photo. 2), the intense contortion which is such a marked feature of the Ordovician is as a rule absent.

The actual contact between the Ordovician black slates can be seen at several outcrops. Three of these are worthy of mention. One is in Blyth's Gully (Loc. D.), about 20 chains N.N.W. from the Wellington-Dolodrook Junction. Another is in the bed of a steep tributary gully of the Wellington, about a mile N.W. of the above-named junction (Loc. E.), and the third is in Thiele's Creek, about

30 chains south from its junction with the Dolodrook (Loc. F.). In all these instances, conformity of strike and similarity of dip are shown, but the horizontal extent of the exposure is limited, and when the general boundaries of the contiguous formations are traced the evidence in favour of an unconformity is more marked. The lithological break is a sharp one in every case, and the graptolites are abundant in the slates to the junction when they stop suddenly.

Unfortunately, no distinctive fossils definitely recognisable as Silurian were obtained, but a grit containing crinoid impressions was noted at Locality D, and a similar crinoid bearing grit was noted in the Dolodrook valley close to the outer boundary of the Ordovician, confirming the ge-anticlinal interpretation of the structure.

Mr. Chapman states that the material, though not conclusive, is lithologically similar to fossiliferous grits of Silurian age collected by Mr. Whitelaw in the Wood's Point Belt, where they bear a similar relation to the underlying slates.

This series is of great extent, wrapping round the Ordovician and older rocks, and forming a wide area of hill country.

From its furthest limit, in the north of the Carey River, where it disappears under the Upper Palaeozoic rocks, southwards to the vicinity of Glenmaggie, where it passes under the Tertiary plains, is a distance of more than thirty miles in a straight line.

It is the outer zone or ring of the complex Lower Palaeozoic inlier and the Upper Palaeozoic cover is found continuously along its eastern limits, approximating to the Avon watershed.

On the west denudation has been more effective, so that the Upper Palaeozoic over-mass is wanting between Hickey's Creek and the plains, a distance of about twelve miles.

The rocks, therefore, regarded as Silurian, can thus be traced continuously to the Macallister Valley to the south of Hickey's Creek, and thence westerly to the Wood's Point-Walhalla zone, included in the surveys of Messrs. Whitelaw and Baragwanath, respectively.

Within the area mapped several of the prominent elevated points rising to well over 3000 feet, are due, to the superior resistance to weathering of some of the hard quartzitic sandstone of this series. The three most conspicuous and noteworthy are Mts. Hump, Margaret and Ronald.

Upper Palaeozoic.—The rocks here considered form a portion of

the most extensive occurrence of this age found in Victoria. The extent of the whole belt from its southern border, where it is contiguous with the Gippsland plains to the northern limit toward Benalla, is about 100 miles, and the greatest width is about forty miles. The general trend of the belt is about N.N.W. It is composed in part of sedimentary rocks, consisting chiefly of thick conglomerates, coarse sandstone and chocolate shales and mudstones, with in places interbedded acid and basic lava flows. The sedimentary series in the vicinity of Mansfield contains fossil fish of Lower Carboniferous types, associated with Lepidodendron.

The strata of the southern portion are very similar lithologically to those of the Mansfield area, but with the exception of an imperfect fish scale, the only fossils obtained were those of Lepidodendron, found in widely separated localities in the Macallister valley, and also that of the Avon. The Geological Survey Map shows this series as Upper Devonian, and the Mansfield region as Carboniferous, but the evidence in favour of their separation is inconclusive, and they are here all regarded tentatively as Lower Carboniferous.

In addition to the above group of rocks, there is a great development in the northern portion of the belt, and particularly in the valley of the King River, of acid porphyritic rocks, which, according to Professor Skeats (28), appear to be related to the dacites, suggesting their correlation with the dacites of the Strathbogies and elsewhere, which are generally regarded as of Lower Devonian age. This is in conformity also with the field evidence of A. E. Kitson (10), who interprets them as being uncomformably overlaid by the Upper Palaeozoic sediments.

Along the western margin of the Upper Palaeozoic belt is the Barkly Valley, notably on Fullarton's Spur. O. A. L. Whitelaw shows in his map the occurrence of porphyritic rocks, some of which Professor Skeats has recognised as altered andesites, distinct from the acid lavas of the Wellington area, and comparable most probably with some of the Lower Devonian volcanics, typically known as the "Snowy River Porphyries."

Another interesting feature is brought out by a study of the geological map of Victoria, with reference to the eastern and western adjoining formations. On the eastern side the older rocks are Upper Ordovician; no Silurian has yet been recognised.

To the west, and continuing to the vicinity of the meridian of Melbourne, Silurian rocks prevail, with only relatively narrow inliers of Upper Ordovician.

Should more detailed work later fail to discover any Silurian rocks to the east of the Upper Palaeozoic belt, it would seem to point to the possibility of an old eastern shore line of the Silurian sea, which is now buried beneath the latter rocks of this area.

The whole Palaeozoic history of this belt, with its succession of sedimentary and volcanic events emphasises that it has represented a major tectonic and structural zone throughout Palaeozoic times.

The two areas where the Upper Palaeozoic rocks have received most attention from me are the vicinity of Mt. Wellington and the Macallister valley, at Hickey's Creek. These two areas will be considered separately.

Wellington Area.—The position and extent of these rocks within the area discussed is shown on the map, and their relationship to the underlying rocks is indicated in sections, numbered 1, 2, 3 and 4. It will be seen that they rest unconformably on the Silurian and older rocks, and in general the beds dip at low angles with a marked absence of the sharp repeated folds of the older series.

On the western side of the map it is seen that the beds dip uniformly westerly (W.S.W.), and on the Wellington side the dip is easterly. These two directions have been proved to form part of a large anticlinal fold at least fifteen to twenty miles in width. The axis has a direction of about N.N.W. and lies between Mt. Tamboritha and Mt. Wellington. The southern portion has suffered much denudation, with the result that within the area examined, the crown of the fold has entirely gone, revealing the underlying older rocks, which have, in turn, been much dissected during the present cycle of erosion. The two limbs of the folds are preserved with their steep scarp slopes opposing one another, forming, especially in the case of Mt. Wellington, bold and precipitous cliffs. (Photo. 3.)

The rock succession is very constant over the whole area, though the thickness of the individual beds is subject to some variation, and in general the observations of Murray (9) and Howitt (4) in other portions of this region, indicate the same succession and features.

The basal beds almost everywhere consist of reddish conglomerates, breccias, or breccio-conglomerates, with pebbly sandstone and red shaly bands developed locally. The pebbles and boulders consist chiefly of quartz and quartzite, with some indurated shale and cherty slate.

One feature of importance is the occurrence also of acid igneous

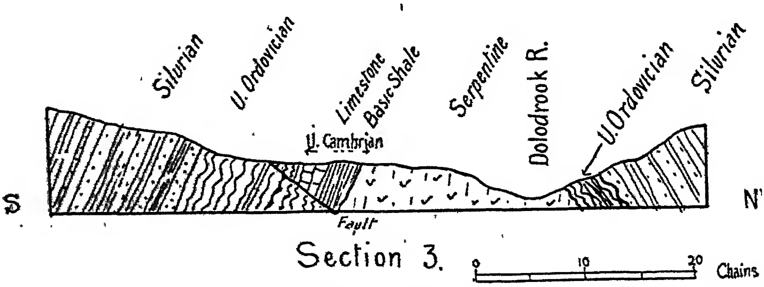
fragments and boulders. Some of these are exactly similar to the rhyolites and rhyolitic porphyries of the Wellington series which overlie these beds. Others are too decomposed for definite comparison.

No outcrop of Lower Devonian igneous rock has been recognised in the area, but as indicated previously rocks probably of this age occur about ten miles to the N.N.W. at Fullarton's Spur and about forty miles to the N.N.W. in the King River District.

From a comparative microscopic examination of numerous thin sections of Lower Devonian porphyries with those from the Wellington area, the details of which will be given later, it appears probable that a satisfactory distinction may be made microscopically between the two series.

If this feature is proved by wider investigation to enable a generalisation to be made, it may be possible to recognise in these conglomerates and breccias, porphyries of two distinct periods representing material derived from a Lower Devonian source, and also later rocks belonging to the first products of the outbreak of the Lower Carboniferous volcanic activity.

A considerable thickness of acid lavas and tuffs succeeds these basal beds over wide areas, and it seems likely that though the main outburst and effusion slightly succeeded the deposition of the conglomerates, some of the earliest outbursts were practically contemporaneous, contributing some of the admixed igneous material which suggests the nature of volcanic ejectamenta.



Section 3.
Roan Horse Gully

One of the best sections showing the basal beds where the breccia character predominates is at Locality G, Wellington River, about three-quarters of a mile below the Wellington-Dolodrook junction. The beds are of a coarse nature, and contain both angular and water-worn rocks, consisting largely of black

cherty slates, quartzites and quartz; stratification is visible, and the beds are here inclined at a much higher angle than usual, dipping to the W.S.W. at about 70°. They are seen to rest against the Upper Ordovician cherty slates, which are much contorted, and the junction suggests a fault line, striking north-westerly. The same beds show a marked discordance in strike at another outcrop, about fifteen chains to the north-west, where there appears to be a short north and south fault. The strike on one side is about N.E., and on the other N.W .

The belt as a whole, however, is traceable almost continuously without any noteworthy break, below the overlying rhyolite sheet, and these disturbances in dip and strike, though striking, are only of limited extent.

Another deposit with some special features is exposed in the bed of the Wellington River, still further to the north-west at Locality H. Its exact nature and relationship is not clearly understood, but it may be an extreme lithological variation of the basal beds under discussion. The extent is about 20 chains over about a width of one chain along the bed of the river.

Its character is that of a coarsely fragmental deposit, composed very largely of fine grained diabasic rock, the interstices being filled up with granular quartz and calcite. A few angular inclusions of quartz porphyry similar to that of the Wellington series were noted.

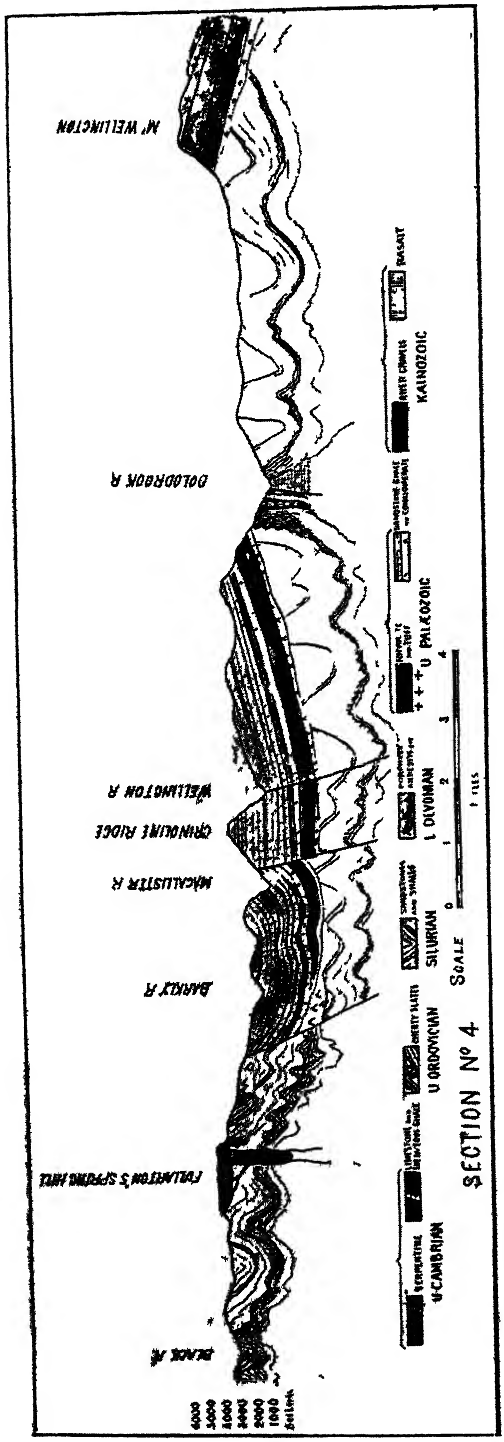
A number of thin sections from various parts of this deposit were examined.

The diabasic material is fine grained, and much altered. Fine plagioclase laths and magnetite are recognisable, but there is much chlorite and calcite. The interstitial material is siliceous and calcareous, consisting of a coarse to fine grained mosaic of quartz and calcite.

Secondary silicification affecting both the diabase and the interstitial material is recognisable, but an original fragmental character can be recognised in some sections, showing altered fragments of shale and diabase, irregular grains of quartz, showing secondary growth and an occasional fragment of orthoclase.

The porphyry inclusion shows a fine microcrystalline siliceous base, with corroded and embayed orthoclase phenocrysts, showing some kaolinization and secondary silicification.

These acid igneous inclusions suggest possibly a Lower Carboniferous source, and though the relationship of the deposit to the


M^t WELLINGTON
DOLODROOK R
WELLINGTON R
CRINOLINE RIDGE
MACALLISTER R
BARKLY R
FULLARTON'S SPRING HILL
BLACK R
U-CAMBRIAN
U ORDOVICIAN
SILURIAN
L DEVONIAN
U PALÆOZOIC
KAINOZOIC
SCALE
SECTION N^o 4

surrounding rocks is not clear, the occurrence is included tentatively with the basal beds of the Upper Palaeozoic.

The Rhyolites and Associated Tuffs.—These rocks occur as a well defined sheet of great extent. They are readily traced in the field, consistently near the base of the series along either limb of the main anticlinal fold. They vary in thickness from less than 1000 to over 2000 feet. In the thinnest portions they would appear to represent a single flow, but in Mt. Wellington where they form a bold escarpment on the western face, they are composed of successive beds of pyroclastic material and rhyolitic flows.

These rocks, under the name of quartz-porphyries and felsites, were recognised by Howitt and Murray, in widely separated areas in this region, and they were invariably found occupying a position towards the base of the series. Howitt recognised the volcanic nature of the rock, and that there were both effusive and pyroclastic representatives. One of the finest sections, that of Snowy Bluff in the Moroka Valley, to the north of Wellington, has been carefully described by both Murray (9) and Howitt (4).

The rhyolitic rocks there rest on conglomerates, and are estimated at about 100 feet in thickness. One of the striking features of much of the igneous material in the vicinity of Wellington is that rocks of the outward appearance of quartz-porphyries, are often crowded with water-worn pebbles of quartz and quartzite, often producing quite a conglomeratic appearance. Numerous inclusions of indurated slate and shale are also common.

Thin sections of some of these rocks have shown that the igneous material of which they are in part composed, is pyroclastic. One particularly fine example from the northern shore of Lake Karng, Mt. Wellington, showed the tuff character remarkably well (microphoto.). It contains angular and broken fragments of quartz and felspar set at all angles in a fine microcrystalline base, containing beautifully preserved tubes of irregular outline so characteristic of tuffs, but seldom so well preserved. Their bent and twisted shapes and broken cusp-like forms are particularly striking in the section.

The fact that material of this nature is often admixed with waterworn pebbles of the old rocks, points to the conclusion that explosive volcanic action was practically contemporaneous with the deposition of part at any rate of the basal conglomerate beds.

Another section from the southern shore of the lake has been referred to in a previous paper (13). It has the character of a rapidly-cooled lava and shows very fine perlitic structure.

The rock on the summit of the plateau is a typical banded rhyolite, the flow lines being very conspicuous.

The detailed succession of igneous material building up the Wellington mass has not been worked out, but there is a noteworthy thickening in the vicinity of Lake Karng. In the southern bluff of Wellington the thickness is not more than 1,000 feet, but in the vicinity of the Lake it is more than double that amount. This is probably accounted for mainly by the presence of marked irregularities of the Palaeozoic surface on which the volcanic beds were laid down.

It is perhaps strange that no undoubted vent or fissure by which the volcanic material reached the surface, has yet been definitely recognised, nor have any dykes, acid or basic, been noted in this region. Considering the high melting point of rhyolite, its viscous nature, the deep dissection of the rocks, and the wide extent of the lava flows in this region, it is perhaps remarkable that some channel by which it reached the surface has not yet been recognised.

No undoubted intrusive quartz-porphyries have yet been noted in this region.

A fine section of the rhyolite, showing its relations to the basal conglomerates and over-lying sandstones, is shown in the course of the Wellington, just north of Shaw's Gap, or one mile and three-quarters in a straight line north-west from the Wellington Dolodrook junction. (Loc. 1.) Here the river has cut a tortuous canyon for about half-a-mile through the rhyolite, forming precipitous cliffs, showing fine columnar structure. (Photo. 4.)

The remaining portion of the series, amounting to some thousands of feet in thickness, consists largely of alternating beds of conglomerate, passing into pebbly sandstone and normal gritty sandstone, separated by beds of varying thickness, of purple shales and mudstones, with, in places, interbedded sheets of altered basalt. (Melaphyre of Howitt.)

Fossils are rare throughout the series. The first obtained came from the sandstones of the Avon River, and were described by Sir Frederick McCoy as Lepidodendron Australe. The writer has since noted Lepidodendron at four localities in the Macallister basin. They are as follow:—

(1) Roadside cutting near Basin Flat.
(2) Roadside cutting, Macallister R.—Target Cr. Junction.
(3) Reid's Selection, near Barkly R.
(4) Near Glencairn (Mr. Sweetapple's).

The only other fossil obtained was a fish scale, from near the Wellington-Dolodrook junction, regarded by Mr. Chapman as probably belonging to the rhizodont genus Strepsodus (23)

The general nature of the beds, together with the contained fossils, indicate a freshwater or lacustrine origin, and the shape of the basin appears to have been that of a long relatively narrow trough, at least a hundred miles in length, with a general N.N.W. direction.

The Melaphyres.—These have been referred to briefly in a former paper (13), and two analyses by G. Ampt were included. Reference is also made to Howitt's description of the melaphyres of Snowy Bluff, where at least eight distinct flows separated by beds of sandstone and shale have been recognised, but they are never of any great thickness (7).

Until last year, no melaphyre had been noted within the area under consideration, but one occurrence can now be recorded in Wallaby Gully, towards its head.

The section forms a small fall in the channel of the creek, showing a bed of melaphyre twelve feet thick resting on red shaly mudstones, with a thin band of mudstone on top followed by sandstone. The flow is distinctly amygdaloidal at the top and bottom with the usual secondary quartz, calcite and epidote. The central portion is a dense fine grained rock. A thin section of this shows under the microscope a distinct flow structure due to the parallel arrangement of the felspar laths. These have a low extinction angle, and appear to be oligoclase; they are ophitically enclosed in chlorite into which all the augite has passed. Analyses of this rock are not very satisfactory on account of the great amount of alteration which has taken place. The one here submitted is from the central portion. The low amount of lime and magnesia is probably due to secondary leaching, for calcite amygdales are common in the upper and lower portion and thin sections of these parts also show calcite.

For comparison the two analyses by Ampt of samples from the basin of the Moroka are repeated. No. 2 was the freshest sample and, therefore, probably the most normal.

The Melaphyres are clearly subaqueous basic lava flows, and are always found considerably higher in the series than the Wellington Rhyolites.

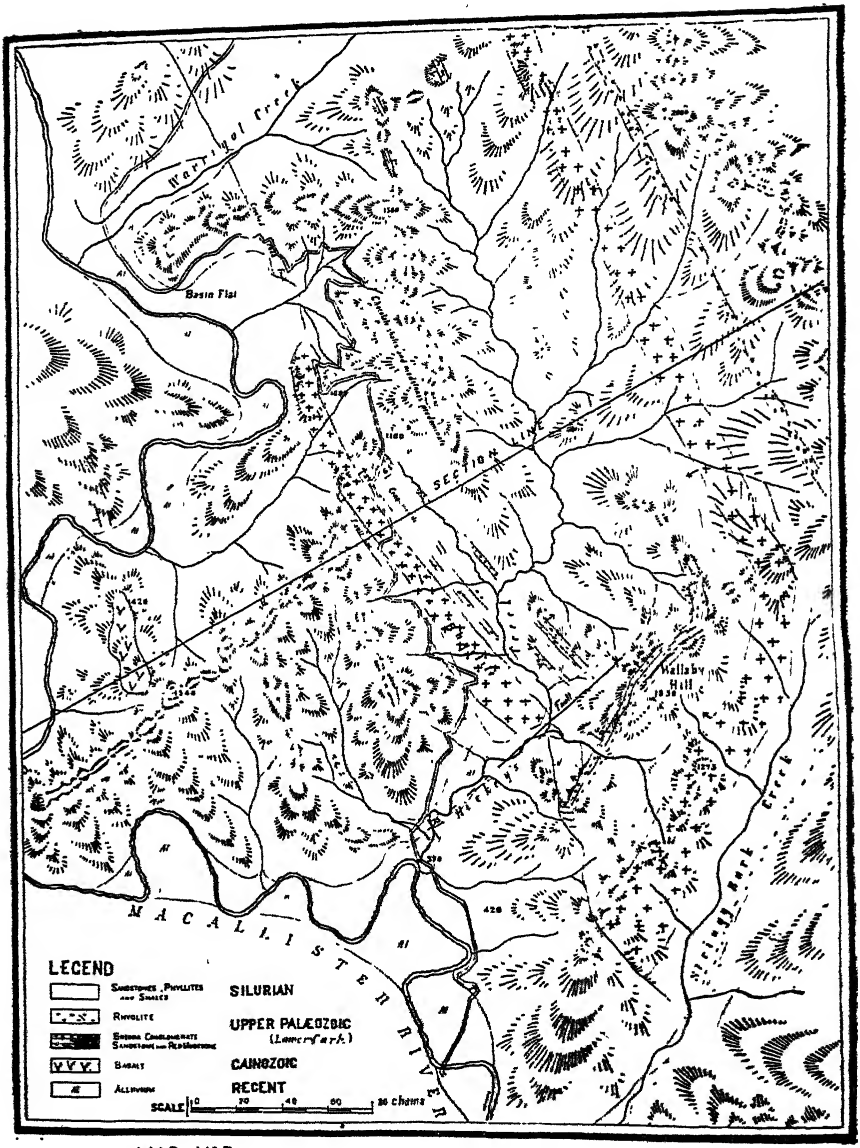
	1	2	3
SiO_2	47.84	49.35	43.88
Al_2O_3	16.17	17.61	16.58
Fe_2O_3	9.28	1.50	5.83
FeO	8.64	9.72	9.11
CaO	4.70	7.71	9.60
MgO	2.62	3.17	5.77
Na_2O	4.47	3.10	2.02
K_2O	0.08	1.56	1.06
P_2O_5	tr.	tr.	tr.
H_2O	0.06	0.65	0.64
H_2O	2.51	2.56	2.22
TiO_2	2.68	2.83	3.52
MnO	0.30	0.07	tr.
Pyrite FeS_2	—	0.34	
	99.35	100.17	100.23
S.G.	2.82	2.918	

1. Melaphyre (No. 177), Wallaby Creek, Wellington Valley. —Analyst E. O. Thiele.
2. Melaphyre, Moroka Snow Plain; fairly fresh sample. —Analyst G. Ampt.
3. Melaphyre, Bad Spur, Moroka Valley; altered specimen. —Analyst G. Ampt.

HICKEY'S CREEK DISTRICT.

This is a relatively small area on the eastern side of the Macallister valley, at Hickey's Creek junction, about twelve miles from Glenmaggie (see Map 3). It lies on the route from Heyfield to Mount Wellington, via the Macallister Valley, and therefore had been frequently traversed during the journeys to and from the Wellington region.

Here particularly, as well as at other points further north in the Macallister Valley, the Upper Palaeozoic rocks had been noted to be very highly inclined, with dips ranging up to nearly vertical, and sometimes in the reverse direction to the normal one. It was therefore decided to give a little time to a more detailed study of the features, with the result that some interesting structural points are brought out, marking a powerful tectonic line running approximately N.N.W., and probably continuing for a great distance in this direction, coinciding very closely with the western boundary of the Upper Palaeozoic series. A new road for vehicular traffic in place of the old pack track has recently been made as far as the junction of Target Creek with the Macallister, about thirty miles from Glenmaggie. At Hickey's Creek, this road leaves for a time



MAP N° 3

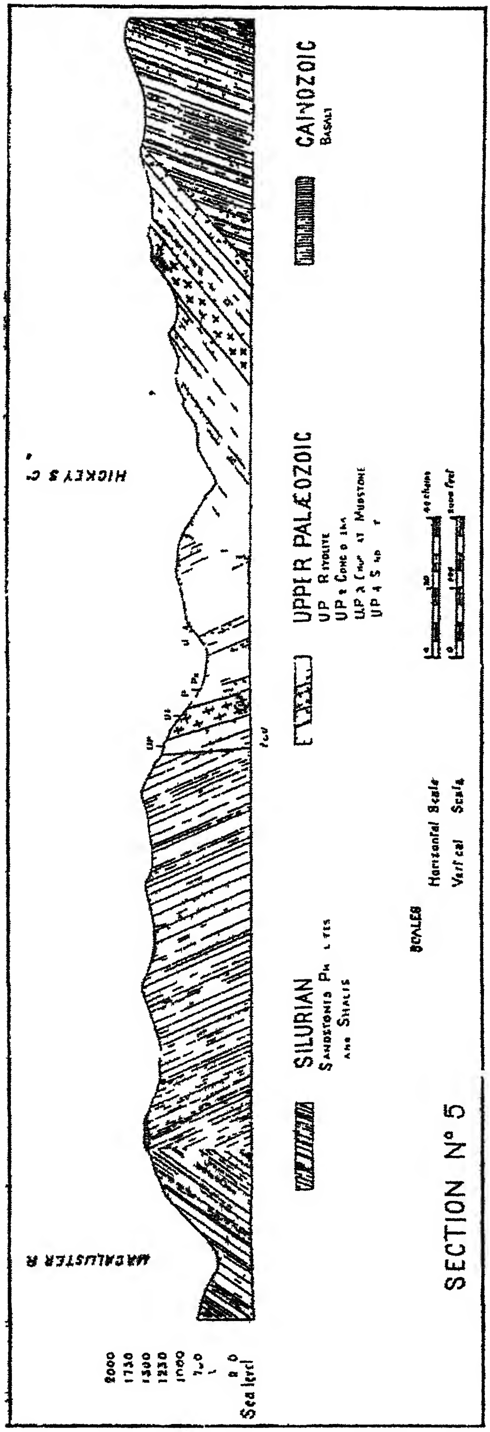
the Macallister, and rises by a long sidling grade more or less parallel with the valley of the creek to a saddle, thence descending to the Macallister again at Basin Flat by a similar winding grade cut out of the steep hillside. This part of the road affords a succession of fine sections of the highly inclined Upper Palaeozoic rocks.

including the basal beds, rhyolite, conglomerates, sandstones (in one place containing Lepidodendron), purplish shales and mudstones. The area mapped includes this part of the road, and the Hickey's Creek Basin essentially, most attention being given to the Upper Palaeozoic rocks, and their contact with the older rocks. The only other formations noted are the Silurian sandstones, phyllites and shales, and a small remnant of a Kainozoic basalt flow.

Silurian.—The usual alternation of quartzitic sandstones with phyllites and shales is found in this area, but the phyllites and shales predominate over the sandstones. They are generally greenish in colour, due to a certain amount of chlorite, and are fairly arenaceous. The whole series is intensely folded and frequently crushed. Small quartz veins are very abundant either along joints, shear planes, bedding planes, or fracture lines.

Upper Palaeozoic.—The rocks belonging to this series are identical in character and succession with those described in the Wellington area, but their high angle of inclination is a striking feature.

The prevalence of thick beds of conglomerates, and coarse pebbly sandstone, and the general red colour of most of the beds, especially the shales, combine to form a striking contrast with the Silurian rocks. The boundaries as a rule are, therefore, readily traced in the field, and also certain characteristic beds within the series can be easily followed for considerable distances, and these are of great assistance in working out the structure. In this way the rhyolite and associated conglomerates were found in following across the strike to be repeated on account of a marked synclinal structure, but as the mapping shows it is not of a simple character, for one limb is bent round in such a manner in the vicinity of Wallaby Hill as to bring the strike of similar beds at right angles. This point is perhaps the most striking feature in this area, for it forms a precipitous rocky crag rising on the eastern side of Hickey's Creek. It is composed of beds of coarse conglomerates dipping at 50 degrees to the N.W. and striking N.E. The beds are cut through towards the southern end by a small tributary of Hickey's Creek causing a rocky cleft, which isolates another rocky crag of slightly lower elevation, and composed of the same conglomerate. Following these beds along the strike in a N.E. direction, they soon swing round to N.N.W., and the same feature is noted with regard to the underlying rhyolite and basal conglomerate. The same rhyolite and conglomerate can be noted on the western side of Hickey's Creek, dipping in the opposite


SECTION N° 5
SILURIAN
UPPER PALÆOZOIC
CAINOZOIC
BASALT
SCALES
Horizontal Scale
Vertical Scale
HICKEY'S C^K
MACALLISTER R
Sea level

direction at a high angle. Fine sections are shown in the road cuttings, about two miles northerly from Hickey's Creek junction (see 12). From about this point, also looking south-easterly across the deep valley of Hickey's Creek, there is an interesting view of Wallaby Hill, showing on the upper portion bare dip faces of the conglomerate striking at right angles to the direction of view. At the same time, in the lower slopes, there are conspicuous outstanding ribs of conglomerate and sandstone dipping at a high angle to the north-east, and whose strike therefore is at right angles to the rocky face forming the summit.

Faults.—Reference to Map 3 and Section 5 of this area shows that an intense compressional movement at right angles to a N.N.W. axis has nipped in and folded a belt of the Upper Palaeozoic sediments in a trough of older rocks. Along the western contact, at several places, the rocks are disturbed and often much crushed. A fine example of crushed rock is seen in Hickey's Creek, close to the old pack track, and about three-quarters of a mile from the Macallister junction. Here a portion outcrops as a conspicuous monolith, about thirty feet high. It consists of broken Silurian quartzite, forming a rough breccia, but distinct from the basal breccias and conglomerates of the Upper Palaeozoic, which are clearly of a detrital nature. Tracing the contact along in a north-north-westerly direction, it is found that in addition to the crush features a portion of the basal beds is cut out, the features in general therefore indicating a persistent fault along this line.

Transverse sections across the Macallister valley at intervals to the north, beyond the area included in this map, would seem to indicate similar structural conditions. The western limb of the broad anticlinal fold has been bent back to form a minor syncline, and faulted against the older rocks on the west. This same feature is recognisable still further north along this line in the map, and section of Woods' Point sheet by O. A. L. Whitelaw, and a generalised section compiled from that map and extended to the east from my own observations seems to provide a probable interpretation of the structure (Section 4). A minor fault with a north-easterly direction intersects the major one, and corresponds in position with the lower portion of Hickey's Creek, but it is the other direction which is of greatest importance.

The age of this tectonic movement cannot be fixed closely. It is clearly post Lower Carboniferous, but may still be Palaeozoic, though it seems probable that renewed differential movement may have

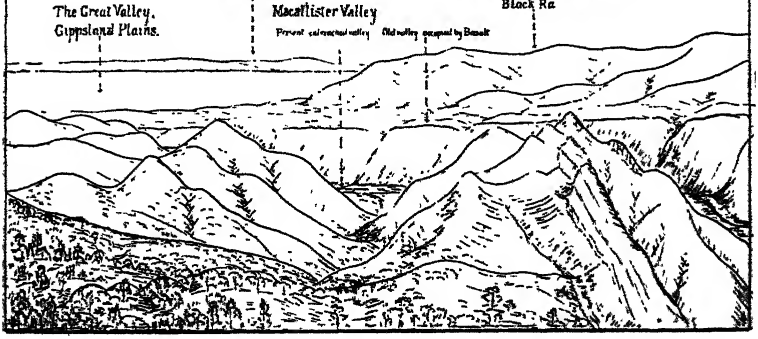
taken place along this line at successive intervals during the late Kainozoic uplift, which produced the existing highlands. The position and general direction of the Macallister valley coincides in part with this line, and some of the physiographic features suggest at any rate that its course has been controlled to some extent by this feature.

Kainozoic Basalt.—The extent of this rock is small, it is but a remnant of an extensive flow which once occupied the valley. It is about a thousand feet above the present stream bed, and was at one time clearly continuous with other more extensive fragments, which are to be found chiefly to the south in the vicinity of Blanket Hills, where the basalt forms a striking shelf about 800 feet above the existing stream, which is now entrenched to that amount along the eastern margin.

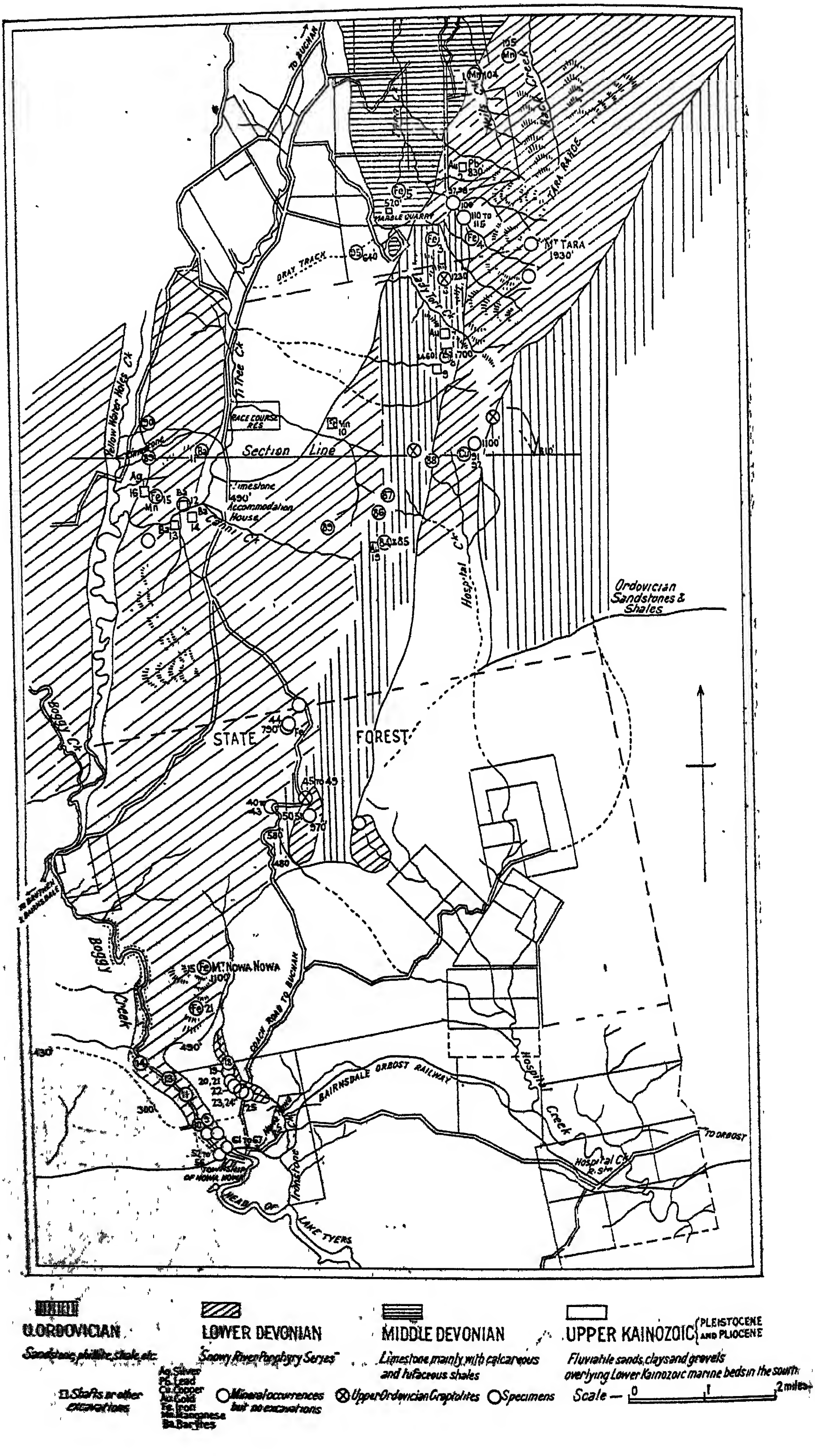
A fine view of this feature is seen from Wallaby Hill, showing also the sudden termination of the Highlands in the south, a portion of the plains of the Great Valley of Victoria, and the Southern Highlands in the distance. (See Sketch A.) The basalt of Gippsland generally is usually regarded as the Older Basalt, and may, therefore be at least pre-Miocene. There is no satisfactory petrological distinction, by which the various Kainozoic basalts can be recognised.

It is, therefore, often very difficult to correlate many of the lava flows in even adjacent areas. For instance, the high N. and S. ridge to the west of the Macallister, from Mount Useful in the south, where it forms the divide between the Thompson Valley, to Connor's Plains in the north, where it is part of the Main Divide, is capped at intervals with basalt resting on river gravels. These

Sketch A



MAP 4.


TO BUCHAN
MARBLE QUARRY
DRAY TRACK
Mt TARA
930'
TARA RANGE
Back Creek
Section Line
RACE COURSE RES
Yellow Water Holes Ck
Ti Tree Ck
Limestone
490'
Accommodation House
Camp Ck
Hospital Ck
Ordovician Sandstones & Shales
STATE
FOREST
Boggy Ck
Boggy Creek
Mt NOWA NOWA
1100'
COACH ROAD TO BUCHAN
BAIRNSDALE ORBOST RAILWAY
Hospital Creek
TO ORBOST
Hospital Ck R. Stn
TOWNSHIP OF NOWA NOWA
Ironstone Ck
HEAD OF LAKE TYERS
U. ORDOVICIAN
Sandstone, phillite, shale, etc.
LOWER DEVONIAN
"Snowy River Porphyry Series"
MIDDLE DEVONIAN
Limestone mainly with calcareous and tufaceous shales
UPPER KAINOZOIC
PLEISTOCENE AND PLIOCENE
Fluviatile sands, clays and gravels overlying Lower Kainozoic marine beds in the south
Shafts or other excavations
Ag. Silver
Pb. Lead
Cu. Copper
Au. Gold
Fe. Iron
Mn. Manganese
Ba. Barytes
Mineral occurrences but no excavations
Upper Ordovician Graptolites
Specimens
Scale
0
1
2 miles

form some of the highest points of the surrounding highlands.

The Mount Useful Basalt is only eight miles in a straight line to the west of the outcrop here described, and yet it is 3300 feet higher. It apparently marks the line of an old valley parallel with the present Macallister, and one question that at once suggests itself is to account for this great difference in altitude. The two alternatives which seem to be most worthy of consideration are, first, that the two basalts represent flows of totally distinct periods in Kainozoic times, and, second, that if of the same age, there has been most extensive differential movement parallel with this line in late Kainozoic times; which view is correct it is impossible to say, but on physiographic grounds I am inclined to favour at any rate a certain amount of differential movement. This will be referred to again later.

In this section the rock is seen to be a typical olivine dolerite, with a well-developed ophitic structure, violet brown titaniferous augite enclosing oligoclase. Olivine and magnetite are abundant. The section from the Hickey's Creek area is similar to that from Blanket Hills, but is of a slightly finer grain, and contains more olivine. The specific gravity of the latter is 2.81.

The District of Nowa Nowa. (Map 4.).

The region here described extends from Nowa Nowa, at the head of Lake Tyers, northward to within about four miles of Buchan, a distance of about sixteen miles. It lies to the west of the Snowy River, and includes the southern termination of the great belt of volcanic rocks known as the "Snowy River Porphyries."

As previously indicated, this region was chosen for examination mainly for two reasons:—(a) To examine certain outcrops of cherty rocks, which had been briefly referred to by Dunn (24) as "Heathcotian," and (b) to study some of the features of the Lower Devonian volcanic rocks.

The late Dr. A. W. Howitt (3 and 5) described the latter series as consisting of accumulations of acid lavas and associated pyroclastic deposits, built up round a line of ancient volcanoes occurring along a meridianal fissure. Certain quartz porphyry occurrences were regarded as probably representing the stumps of some of these old volcanoes.

Since Howitt's contribution, about forty years ago, giving a general description of this interesting and important belt of rocks, there have been no important additions to our knowledge of the region.

Later field work by Murray (25), Ferguson (26), and O. A. L. Whitelaw (27), has added a little to the details concerning the distribution and boundaries in a few localities, but no further petrological work has been done, nor had any chemical analysis ever been made of rocks from the "Snowy River Porphyries."

Professor E. W. Skeats (28), in his paper on the Volcanic Rocks of Victoria, gives a summary of Howitt's description of the "Snowy River Porphyries," dealing with their distribution, geological relations and petrological character. Briefly, they form a north and south belt up to about thirty miles in width, and extending southwards for sixty miles from near the head waters of the Murray, where the highest points rise to over 6000 feet, to the head of Lake Tyers, where they pass under fluviatile and marine Kainozoic deposits at less than thirty feet above sea level. Some doubt has been expressed as to the exact age of these rocks. It has been shown clearly that they are pre-Middle Devonian, but there is some uncertainty as to the lowest limits of the series. Mahony and Griffith Taylor (29), in dealing with the geology of the Federal Territory, compare certain quartz-porphyries of that region with the "Snowy River Series," but they claim that they represent in the Federal area, an Upper Silurian volcanic activity, which continued into the Lower Devonian. In Victoria, the beginning of this important volcanic outburst cannot yet be fixed so certainly, as Upper Ordovician graptolites are the only definite fossils obtained from the older sediments, on which the volcanoes rest unconformably.

Howitt's petrological examination of this rock was of a preliminary nature, and he describes them as quartz-porphyries (in which orthoclase prevails over plagioclase, a point to be referred to again later), felstones (acid lavas), ash and agglomerates.

General Surface Features.—The physiography of the area under consideration will be discussed separately under the section devoted to that purpose. It will only be necessary here to mention a few salient points.

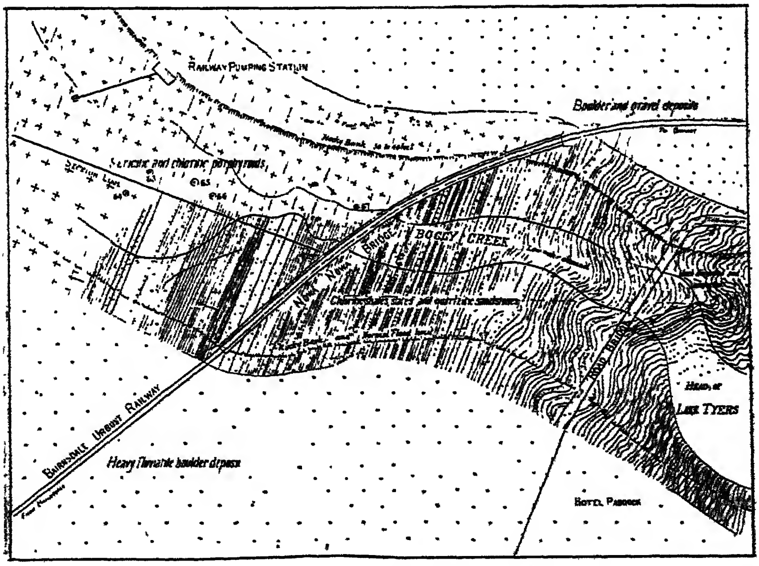
The southern portion is part of a low coastal plain of soft rocks, rising, as a rule, not more than several hundred feet above sea level. The uppermost beds consist of fluviatile grits, sands, gravels and boulder deposits, which, in the south, overlie marine Kainozoic limestones and marls, but further north than about twelve miles from the coast, they rest directly on the older rocks.

The rest of the region forms a low portion of the Victorian Highlands, most of which is below 1000 feet in altitude, and its south-

ern border is less sharply marked off from the coastal plain than usual. Hard rocks of a varied nature have controlled largely the main irregularities of the present surface, and the principal feature is the Tara Range, which runs obliquely across the area in a N.N.E. direction. Starting towards the S.W. corner of the map, at Mount Nowa Nowa (about 1100 feet), the range continues as a rocky forest clad ridge to the N.N.E., rising in Mt. Tara to nearly 2000 feet. The rocks composing it consist of quartz porphyrite and Upper Ordovician slates and sandstones.

The most important streams are Boggy Creek and its tributary, Yellow Water Holes Creek. The former enters the head of Lake Tyers at the township of Nowa Nowa, after passing for several miles through a rocky gorge entrenched in the Porphyry Series, and exposing some of the best sections to be seen in this area. A few of the gullies on either slope of the Tara Range also provide some good exposures, but most of the area is covered with the scrub and forest, and the relationship and boundaries of the rock formations are rather difficult to follow. The task of mapping several portions was further hampered by the want of maps of any kind. The sketch

MAP 5



U TERTIARY   LOWER DEVONIAN   UPPER ORDOVICIAN

SCALE

map therefore accompanying this paper is in many places only a very rough approximation. Most attention was given to the lower portion of the Boggy Creek, and the slopes and gullies of the Tara Range.

General Geology.

The following formations are included within the area, and will be dealt with in turn:—

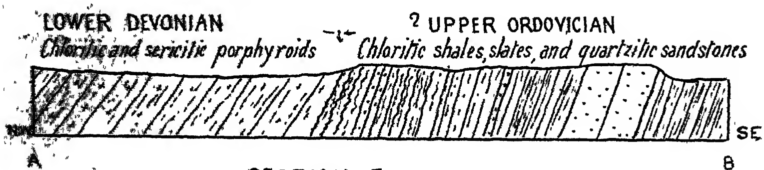
1. Upper Ordovician, consisting chiefly of highly inclined quartzitic sandstones and slates, the latter chertified in parts.
2. "Snowy River Porphyry Series"—probably Lower Devonian in age, and consisting of volcanic rocks, both effusive and pyroclastic, ranging from andesites to acid lavas.
3. Middle Devonian, comprising crystalline limestone and calcareous shales.
4. Kainozoic, ranging from Lower Kainozoic to Pleistocene.

Observations were confined mainly to the first two series.

Upper Ordovician.—This Series consists chiefly of alternating thin beds of quartzitic sandstones, mudstone, shale, phyllite and some cherty slate. There is a marked absence of the black graptolite slates, which are so characteristic a feature of the Ordovician rocks in the Wood's Point and Wellington districts.

Fossils are rare, and frequently imperfectly preserved, but all the recognisable forms have been Upper Ordovician graptolites.

The first record is due to O. A. L. Whitelaw, who obtained graptolites in a road cutting at 5 miles 50 chains from Nowa Nowa, in the Buchan Road. These were examined by the late Dr. T. S. Hall (30), and the forms identified are tabulated in the list given elsewhere. (Table 1.) Three additional occurrences found by myself are marked on the map.



SECTION E

BOGGY CREEK NOWA NOWA

Scale, yards

Five separate areas have been observed within the region here discussed, where rocks regarded as Ordovician have been observed.

Three of these are quite small inliers, two occurring in the bed of Boggy Creek (Secs. C. and E.), and the third in Ironstone Creek (Sec. D.) The relationship to the "Snowy River Porphyry Series" can be studied at all these sections, but its best seen at Section E, Nowa Nowa railway bridge. (See Maps 4 and 5, and Section E.)

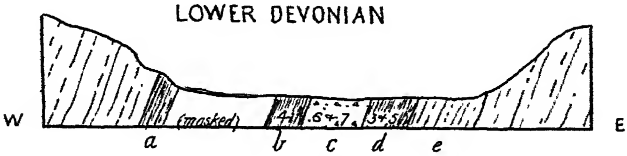
Though the strike and dip of the two series are similar in direction, the junction is seen to be unconformable.

No fossils have been obtained from any of these inliers, but the outcrops at both sections, E and D, appear to be on an extension of the strike of a larger belt to the north, where graptolites have been obtained, and the rocks are lithogically similar. All that can be said, therefore, with regard to the age of the succeeding igneous series is that it is post Upper Ordovician.

The two remaining occurrences are of larger extent, and their position will be seen by reference to Map 5. One occurs as a narrow strip about a mile in width, and nine miles long, with a general bearing a few degrees east of north. It is almost surrounded by the "Snowy River Porphyries." Its southern continuation is masked by the Upper Kainozoic sands and gravels.

These deposits also border it for about two miles along the north-western boundary.

About two-thirds of the length of the belt coincides with the crest of the Tara Range, but at the northern end it lies a little to the west of the watershed.



SECTION A. BOGGY CREEK.

a. Light green chloritic shale. b. Purple shale with sericitic markings.
c. Porphyry breccia. d. Chocolate shale similar to b.
e. Light coloured sheared felsite

Horizontal Scale
Vertical

6.

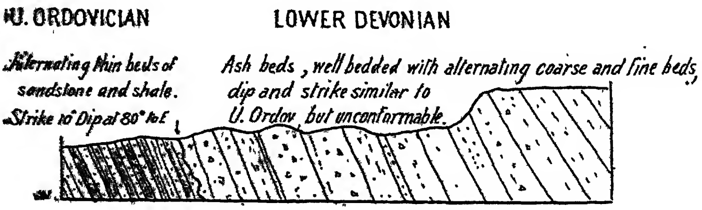
BOGGY CREEK REGION

Mount Tara Goldfield.—It is in the northern half of this Ordovician area, extending over a distance of about four miles, that the now abandoned Tara goldfield is situated (24 and 25). Numerous old prospecting shafts and open trenches occur at intervals throughout the field, but most work has been done at the northern end, in the vicinity of Lady Torr Creek, where there are a number of adits and shafts.

All the accessible adits were examined, and roughly sectioned. These observations, together with those above ground, show clearly that the rocks are very much disturbed, faulted and sheared. The line of crushing and shearing lies between N. and S. and N.N.E., and coincides roughly with that of the old mines. Though some quartz occurs, it does not appear to be in the form of a defined quartz reef, and the lode formation seems to be of the type of a fracture zone of crushed rock with some quartz and gossany material.

The strike of the rocks is generally N. to N.E., but at the northern end of the field there is much variation, north-westerly and even westerly strikes being observed close to the normal direction. This is well shown in some of the adits, where numerous faults with a generally northerly trend are revealed. Most mining appears to have been done at the "Orbost Tunnel" (Au. No. 9 on Map 4), where there are two adits and some stoping has been done along a fault line, striking 10 degrees east of north and dipping W.N.W. at about 65 degrees.

The auriferous occurrences are in general confined to the Ordovician belt, but gold has also been obtained in the porphyry, about half a mile to the north of the termination of the Ordovician. This was at the "Tara Crown," (Au. No. 2 on Map 4), where it was associated with galena. This is probably a continuation of the fracture zone, which intersects the Ordovician.



SECTION C. BOGGY CREEK

Scale

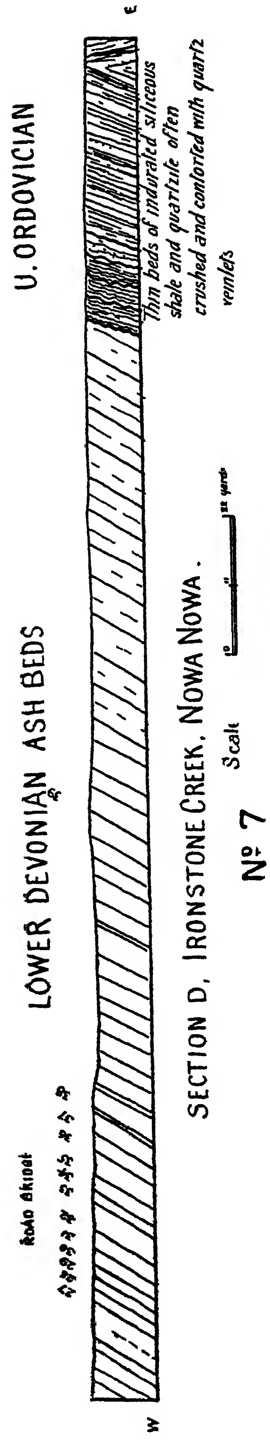
The rocks throughout the gold field, in addition to their sheared features, are frequently somewhat cherty, and on the whole are light-coloured, varying from whitish to creamish, with some superficial ironstaining along the joints and bedding planes. This light colour may be due to extensive bleaching within the zone of oxidation, for occasional loose fragments of black chert are to be found, and there is one occurrence of black chert in situ in the bed of Lady Torr Creek.

Special attention was given to the region of the old gold mines, because it was here that Mr. E. J. Dunn described the occurrence of "Heathcotian" (24), as well as Ordovician. Mr. Dunn observes that "the Tara Range is remarkable that within a mile of the Micawber lease there are three distinct series of rocks carrying auriferous vein-stones."

The three series referred to are Heathcotian, Ordovician and Lower Devonian, and the separation of the first two series appears to be based on lithological differences only, particularly the supposed significance of cherts and jasperoid rocks as a distinctive characteristic of Heathcotian; but here again, as in the Wellington district and elsewhere, this feature loses its significance, for at locality 6, north of Lady Torr's Creek, the author found Upper Ordovician graptolites in light coloured cherty rocks, and in general these rocks are so intimately associated with the more normal sediments, which also yield Upper Ordovician graptolites (locality 18), that there is no valid reason for separating them.

Turquoise.—A little turquoise was found in an old adit in the basin of Lady Torr's Creek. It occurs chiefly along the joints, irregularly distributed in a light-colored felspathic sandstone, and though of interest as another example of its wide distribution in the Ordovician, the specimens obtained did not afford much promise from a commercial point of view.

Gossany Ironstone.—Towards the northern end of the area under consideration (Fe 6 on map), there is an ironstone outcrop, consisting chiefly of limonite. It is roughly elliptical in shape, measuring about 3 chains in a north and south direction, and $1\frac{1}{2}$ to 2 chains across. Much of the limonite is hard and massive, but some contains quartz, and broken up sedimentary rock. The limits are rather indefinite, the deposit passing out into ferruginous shale much crushed and jointed. The strike of the strata is about N.N.E., and the dip appears to be easterly at a high angle. Another similar outcrop occurs about 30 chains to the S.S.W., on the fall to


E
U. ORDOVICIAN
Thin beds of indurated siliceous shale and quartzite often crushed and contorted with quartz veinlets
LOWER DEVONIAN ASH BEDS
SECTION D, IRONSTONE CREEK, NOWA NOWA.
Scale
Nº 7
W

Lady Torr Creek. These occurrences are distinct from the iron deposits in the porphyry, to be referred to later, the latter consisting largely of hematite, while the former appears to be the type of gossany cappings, which may develop into sulphides at a depth. No work, however, has been done with a view to testing these deposits.

Another Ordovician area still remains to be referred to. It forms part of a large region which extends to the Snowy River, and beyond into Croajingolong. Along its western boundary it is in contact with the Snowy River Porphyries. The line of junction has not been accurately traced, but it bears in a general N.N.E. direction. My own explorations here have been very limited, and were confined principally to the vicinity of the Orbost bridle track, and to a rapid reconnaisance along the now disused track to Bete Bolong, on the Snowy River. Some obscure graptolites were found close to the western boundary, with the porphyry, and are probably Upper Ordovician. The general strike as far as observed lies between N. and N.E., and it is worthy of note that this direction is characteristic of nearly all the features in this region as a whole. It is not confined merely to the strike of the strata. The belts of Ordovician, of porphyry and Middle Devonian limestone, also the longer axes of many of the granite batholiths, the major faults, and the trend of the various ore deposits, all conform approximately in this direction. It is in contrast to a north-westerly trend, which is a marked feature over a wide area to the west, and it would appear to be a continuation of the important trend lines of this direction so well developed in New South Wales.

The Snowy River Porphyry Series.—The distribution of the rocks of the series within the area here considered is shown on the map in which the characteristic N. and S. to N.N.E. trend is well shown.

Porphyritic rocks of an acid type and general pinkish to brown colour prevail on the rocky ridges, the highest point in the region culminating in Mt. Tara, about 1930 feet in height.

These rocks being of a relatively hard and resistant nature, naturally form exposures, while large intervening areas are so masked with soil that little idea can be obtained as to the nature of the underlying rock. The spoil heaps, however, of some of the now abandoned mining shafts and other excavations frequently suggest some types, showing considerable variation from the acid porphyries, and allied rocks of the ridges, and the sections in Boggy

Creek reveal the existence of bands of altered andesitic and trachytic rocks.

The fragmental character of much of the rock is frequently apparent macroscopically, and thin sections show clearly that much of the finer material too, though often much altered and silicified, is of a pyroclastic origin.

An alternation of coarse and finer-grained material, with slight indication of bedding, appears to be the general rule, definitely stratified beds being rare. Howitt (3) observes that he had only noted at one place, near Buchan, a section which suggested aqueous assortment and deposition, which he regarded as of limited extent and purely local. Though this appears to be true in the main, in the area under consideration, the outcrops in the southern extremity afford an exception, for at Section A, Boggy Creek, and Section D, Ironstone Creek, particularly, the character and regularity of the bedding are such as to strongly suggest aqueous deposition. In this region also two other exceptional features are worthy of note: the beds are highly inclined, and intensely sheared, the latter agency having converted the rocks into typical porphyroids. These are best developed at Section E, Nowa Nowa railway bridge. The schistose character is marked along the Boggy Creek Gorge for nearly a mile above the railway bridge, but gradually disappears beyond this. The direction of schistosity corresponds with that of the strike of the different beds, being in a general N. to N.N.E. direction. As the course of the stream bed is here about N.W., it is a favourable one for exposing a good line of Section. For general and petrological description, it wil be convenient to group the rocks as follow :—

(a) Porphyroids.
(b) Stratified ash beds.
(c) Trachytic and andesitic rocks.
(d) Acid porphyritic and pyroclastic rocks.
(e) Ceratophyres.
(f) Granitic rocks.

The Porphyroids.—These rocks form a rather striking group, for their schistose structure, and often also a sheen or lustre due the development of sericite give them a distinct lithological character. Their junction with the underlying sediments, presumably Upper Ordovician in age (Section E, Boggy Creek), is sharp and unconformable. They are again exposed in the bed of Ironstone Creek (18-22), and still further to the N.E. towards the head of one of the branches of Bill's Creek (below No. 68).

In general these rocks are usually light in colour, varying from light cream to pale green. Sometimes their fragmental character can be recognised macroscopically. In Section A, No. 6 specimen represents a coarse crushed porphyry breccia, with red jasper shale and chloritic inclusions. The mechanical stresses have developed a considerable amount of sericite and thin sections show in addition secondary silicification. The red jasper has the appearance of an altered igneous rock, possibly a diabase or andesite; traces of felspar can be recognised, and hematite is disseminated through it. Fragments of fine grained acid igneous rocks are also present.

On the other hand, many of the rocks of this group have a very fine texture, with their original character so altered that even thin sections may not give any satisfactory evidence concerning their primary nature, but, on the whole, the microscopic examination clearly points to the fact that they are dynamically altered acid porphyrites and ash beds.

Specimen 1, Boggy Creek, is a hard schistose rock, which in the thin section, shows a distinctly fragmental character. There is a fine micro-crystalline base of quartz and felspar, in part sericitic, and set with irregular fragments of plagioclase and quartz, the former predominating. The felspar is probably an oligoclase-albite. Vivid green chlorite is abundant as well as sericite.

No. 2 is a light grey porphyroid, the thin section showing abundant sericite and no chlorite. Small fragments of plagioclase felspar are present.

No. 18, Ironstone Creek, is a sericitic rock of similar type, with recognisable granular quartz, but all trace of the felspar has been obliterated.

No. 19, Ironstone Creek, is a coarse-grained sericitic rock, with a definite schistose structure. Occasional plagioclase fragments are recognisable, and some chlorite is present. Among the inclusions one fragment may represent an altered andesite. The result of intense stress is well shown.

A belt of these porphyroids, 10-12 feet wide, in the bed of Boggy Creek (No. 63, Map 5), is highly pyritic, and micaceous hematite is widely distributed, frequently sparsely disseminated and associated with red jasper and ordinary quartz, but occasionally moderate outcrops of fairly pure hematite can be observed. More often, however, the ore is highly siliceous and lenticular in occurrence. The iron ores, however, are not restricted to the porphyroids, but the micaceous variety appears to be the characteristic

form occurring in these rocks, and the stresses to which they have been subjected may have been favourable to the production of the micaceous form of the ferric oxide.

One feature worthy of some reference, and well shown at Section E, is the fact that the porphyroids appear to have been more affected by dynamical stresses than the underlying older sediments, consisting of chloritic shales, slates and quartzitic sandstones. They therefore frequently approach typical schists in character, while the adjoining older beds still preserve the appearance of normal sediments. It is probable, however, that the two series may have been subjected simultaneously to stresses of the same order of magnitude, but the nature of the mineral composition of the porphyries and ash beds from which the porphyroids have been derived made them more susceptible to the development of new structures and mineralogical rearrangement.

Stratified Ash Beds.—These beds are best studied at Section A and C, Boggy Creek, and at Section D, Ironstone Creek. The stratification is regular, with an alternation of coarse and fine material, the dip being at a high angle, westerly in sections A and D, and easterly at C. It is well known that a sub-aerial deposition of volcanic ash may result in remarkably regular deposition, and in the absence therefore of definitely aqueous sediments interbedded with the ash beds or of the association of fossils in sedimentary material with the pyroclastic, it may not be possible to decide whether the beds in question are really sub-aqueous or not. The fine, purple shales, beds b and d, Section A, however, resemble very closely true sub-aqueous sediments, and may, in fact, be such. No. 16, Section C, may be taken as one typical example of the normal bedded ash beds, though the degree of coarseness naturally varies from bed to bed. This example is a light greenish grey granular rock. A thin section shows well the fragmental structure, with abundant chlorite, angular quartz, and some triclinic felspar and magnetite set in a micro-crystalline base of quartz and felspar, with some secondary silicification.

At Section D the beds are exposed more or less continuously for about 8 chains, and sometimes show a slight amount of schistosity. A good exposure is to be seen under the road bridge. The colour is in general grey, but darker and lighter bands with slight variations in texture bring out the thin regular character of the bedding. Numerous thin sections (27-39) show a general similarity mineralogically. No. 28 is a finely granular grey rock, with a little fels-

par recognisable macroscopically. In the thin section the base is seen to be slightly schistose, and micro-crystalline, consisting of felspar and quartz, and showing some secondary silicification. It is set with angular fragments of triclinic felspar, showing fine repeated twinning after the albite type, and occasionally carlsbad twinning also. Extinction measurements on several of the most suitable sections indicate that the felspar is probably oligoclase-albite. A little sericite and chlorite are also present. No. 38 is somewhat coarser in grain and of a light green colour. The fragmental character and slightly schistose structure are revealed in the thin section; angular quartz fragments are abundant, also altered felspar, and probably some scapolite. Dark, green chlorite and calcite are present as alteration products, and some fine-grained fragments probably represent altered shale.

One feature worthy of mention in connection with the microscopic examination of the above rocks is that all the identifiable felspar fragments noted are triclinic.

Trachytic and Andesitic Rocks. — In contrast to the light coloured siliceous rocks just described, another group of darker and more basic types is met with in Boggy Creek (Specimens 9-14), and so far they have not been traced or recognised beyond the restricted area, in the region here examined. They occur in definite bands, and appear to represent both effusive and pyroclastic beds. Most of the rocks of this type are very much altered, and the original ferro-magnesian minerals are almost invariably altered to chlorite.

No. 11 is a fairly typical example of the andesitic type. It is a dark rock, with pink felspar phenocrysts.

Thin sections under the microscope show phenocrysts of triclinic felspar, slightly cloudy through decomposition, of stumpy habit and with broad twin lamellae. No very satisfactory extinction measurements were obtained, but it may be oligoclase. The ferro-magnesian mineral was probably augite, but it is completely decomposed to chlorite. Magnetite is common. The base is cloudy and altered, but small felspar laths are abundant in it. The rock is regarded as an altered augite-andesite. No. 9 is more altered, showing some serpentinization, and much chlorite. The felspars are abundant and similar in habit to 11, but are kaolinized and carbonated.

No. 12 is a dark, dense rock, slightly porphyritic, with patches of red jasper. The thin section shows a distinct trachytic structure, with abundant felspar laths in a brownish devitrified base.

9A

The largest felspar phenocrysts are inclined to be of rather stout habit, showing somewhat broad twin lamellae, and generally low extinctions, suggesting oligoclase.

The numerous felspar laths, which bulk most largely in the slide, and show simple twinning, are probably sanidine, as also are a number of definitely prismatic forms of intermediate size. Magnetite is abundant, but almost all trace of the original ferro-magnesian mineral has disappeared. Veins and patches of secondary quartz and chlorite are present, and one portion of the slide has been almost completely silicified, showing the quartz both as a mosaic and microcrystalline form stained by patches of hematite and some chlorite.

The rock appears to represent an interesting type of altered trachyte or trachytic andesite.

No. 14 is a dark grey, finely porphyritic rock macroscopically, but the thin section shows a distinct fragmental structure, with abundant angular fragments of triclinic felspar (probably an albite of the type Ab_{19} An_1). Smaller felspar laths are present, some of which are triclinic, with low extinctions, and, maybe, oligoclase, also magnetite and fragments of altered rocks similar to 12, much chloritized. The base is finely granular in part, due to secondary silicification. There are no recognisable original ferro-magnesian minerals, but chlorite is abundant. The rock probably represents an altered andesitic ash.

Acid Porphyritic and Pyroclastic Rocks.—Rocks of this type are very abundant, and show considerable variety of colour and texture. In general a prevailing red to brown colour is most common, but various shades of green to grey are also found.

Flow structure is not common, and was only noted in one place, namely, in the ridge between Ti-Tree Creek and Yellow Water Holes Creek, and W.N.W. from Beecher's.

Quartz and felspar either as fragments or phenocrysts are usually apparent macroscopically, and in thin sections the rocks of this division can generally be readily separated into two groups—

(1) Those definitely fragmental, representing altered pyroclastic material.

(2) Those of the more normal quartz-porphyrite type, probably partly hypabassal, having solidified in the fissures, or vents, through which the more superficial material reached the surface.

Both these types are well represented along the Tara Range.

(i.) *Fragmental Type.*—Sections of this type show all the larger minerals and inclusions as broken and angular fragments, with no embayment. The base is siliceous and finely granular, and among the larger fragments felspar is often more abundant than quartz, and the triclinic form distinctly predominates, orthoclase being rare.

The secondary minerals most abundant are chlorite, and occasionally calcite.

(ii.) *Acid Porphyrites (Non-Fragmental).*—The rocks of this type have perhaps a higher silica percentage than normal porphyrite, and this may in part be due to a certain amount of secondary silicification and alteration.

The fine grained base of the rock is generally affected to some extent in this way. All the recognisable felspars, however, are dominantly triclinic, orthoclase being more or less rare.

No. 100 is a medium grained porphyritic rock of a red brown colour.

In the thin section the phenocrysts have rather irregular outline, the quartz is partly rounded, and occasionally embayed. The felspars are more abundant than quartz, and occasionally have a regular prismatic outline, but more often are broken and irregular. Twinning after the albite law prevails, but occasional pericline and carlsbad types are represented. The twin lamellae vary from moderately broad to fine bands. Different kinds of felspars appear therefore to be represented. Only a few were satisfactory for determination by extinction angle. These gave readings up to 20 degrees, and are probably therefore andesine.

The optical features of several examples suggest anorthoclase, and the chemical analysis further points to some potash felspar, which, however, has not been definitely recognised microscopically. Magnetite is only moderately abundant. The base is micro- to crypto-crystalline, with some evidence of recrystallisation and silicification. Minute laths and fragments of felspars and quartz are scattered through it.

Chlorite is sparsely distributed through the rock, and calcite is present in moderate amount.

This rock is regarded as a quartz porphyrite. No. 105 is a greenish porphyritic rock, but the chemical analysis corresponds closely with that of the previous example.

The thin section is very similar. Quartz phenocrysts are a little more abundant, and some are beautifully embayed. The felspars

show a similar range and variety. One example has very minute pericline twinning, and may be anorthoclase.

Iron oxides are a little more plentiful; some occur as very minute grains abundantly scattered through the rock. Corroded xenoliths of both fine grained igneous and altered sedimentary rocks are moderately numerous. There is an occasional flake of muscovite, and little chlorite but no calcite was observed.

No. 93 may be portion of an agglomerate. It contains numerous xenoliths, apparently all of igneous origin. One is an altered andesite, the others are red, fine grained felsitic rocks, stained with hematite, and showing small, partly kaolinised felspar phenocrysts. The rest of the rock is generally similar to the previous examples. Some of the quartz is rounded, but only slightly embayed.

No. 91 is a specimen from the Dominion copper mine, now abandoned. It is similar in grain, but lighter in colour than the other examples described, but on exposure suffers a superficial red discolouration, which appears to be due to the presence of some carbonate of iron. Otherwise the minerals present are similar. A little copper pyrites is present in the dump, but as the shaft is full of water, nothing could be seen as to the occurrence of the copper.

Quartz-Ceratophyre.—No. 68.—This rock is of medium grain, porphyritic, but inclined to be granular in hand specimens, and has a general grey colour. The analysis show a silica percentage of 72.41, very similar to that of the acid rocks generally of this district, but in the alkalies there is a marked difference in that soda is 6.86 and potash only 0.13.

It is very closely comparable with certain rocks, described from Navigation Creek, Noyang, by Howitt (32), under the names of quartz-mica-porphyrite and quartz-porphyrite.

Reference to the table with analysis will show the close resemblance.

Professor Skeats, in reviewing the volcanic rocks of Victoria (28, p. 187), quotes Howitt's analyses and gives some additional remarks on these rocks, describing them as quartz-ceratophyres. Referring to one example, he says, "This rock shows a microcrystalline granular ground mass of quartz and felspar, with minute microliths of chlorite, replacing probably amphibole. The porphyritic constituents are as follows:—

Oligoclase of an acid variety, showing both albite and carlsbad twinning. Quartz in corroded and fractured crystals and chlorite pseudomorphs after magnesia-iron-mica."

The above description also concisely describes the features of No. 68. The occurrence of this rock is shown in Map 4, near the head of one of the branches of Ironstone Creek. The outcrop, however, is very limited, being partly surrounded by late Kainozoic sands and gravels.

The relationship to the igneous rocks of the district is not shown, but it is almost certainly later than the earliest members of the Snowy River Series, which show here various stages of shearing with the development of porphyroids. Some of these outcrop in the stream bed a short distance below the ceratophyre.

From the chemical analysis of No. 68, applying the American Classification, it is interesting to note that it falls into the persodic Subrang, noyangose, of liparase, the per-alkalic Rang (1) of britannare, the quardofelic Order (4) of persalane. Class I.

Analysis and Molecular Ratios			And Classification.	
SiO_2	72.41	1.207	Quartz	29.28
Al_2O_3	14.38	0.141	Orthoclase	0.55
Fe_2O_3	2.94	0.018	Albite	58.16
FeO	0.85	0.012	Anorthite	3.33
MgO	1.18	0.029	Corundum	2.84
CaO	0.87	0.015	Hypersthene	2.90
Na_2O	6.86	0.110	Magnetite	2.32
K_2O	0.13	-	Ilmenite	0.45
H_2O+	0.67	-	Hematite	1.28
H_2O-	0.04			
CO_2	-		Class	1
TiO_2	0.26	0.003	Order	4
P_2O_5	0.17	0.001	Rang	1
MnO	0.09	0.001	Sub rang	5
Total	100.85		Magmatic Name, Noyangose.	
S.G.	2.63			

Granite Rocks.—Only one small occurrence of granite has been noted in the area included in the map. It is limited to an exposure of a few chains extent along the bed of one of the branches of the Tara Creek, No. 98. On the west it is in contact with the fragmental igneous rocks of the Snowy River Series. No evidence of contact alteration of these rocks was noted, nor have any dykes or offshoots of granitic rocks into them been observed. It is probable, therefore, that the granite is the older rock. A much more extensive outcrop of granite closely similar macroscopically, and in thin sections also, occurs a few miles to the east of the Tambo River,

and the Bairnsdale-Orbost railway line intersects the southern end of the mass, showing some good sections in one of the cuttings a few miles east of Bruthen. The rock is of medium grain and pink colour, closely resembling the better known Gabo Island granite, with which it is most probably to be correlated genetically. At the locality east of Bruthen, the granite intrudes sedimentary rocks, presumably of Upper Ordovician age.

There is, therefore, no opportunity to study the relationship to the volcanic rocks of the Snowy River Series.

Another occurrence lies to the east of the Tara Range in the vicinity of the now deserted district of Bete Bolong. The granite here takes the form of two elongate elliptical masses more or less parallel, with their longer axes striking north easterly across the Snowy River. The surrounding rocks are entirely sedimentary, again presumably Upper Ordovician. This area was only very hurriedly visited, at one place on the western margin. Two types were noted, one a fine grained aplitic variety, and the other a distinctly hornblendic form without the prevailing pink colour of the types previously mentioned. Distinct contact alteration is shown in the sediments in the vicinity, characteristic hornfels being common. As the area examined at Bete Bolong was very limited, it is impossible to say whether or not the position seen is typical of the whole of the area.

Thin sections of the granite from all the above localities were examined.

No. 98, Tara Range, and that from near Bruthen, most nearly resemble each other, but hornblende is most abundant in the Bete Bolong example.

They all agree in having at least three types of felspar—orthoclase and two triclinic forms; much of the felspar is partly kaolinised, and, therefore, unsuitable for determining accurately the relative proportions, but approximately the monoclinic and triclinic forms appear to be about equal in amount. One triclinic form is well zoned with moderately broad twinning, while a less common type has exceptionally fine twinning, often of the pericline type, and with undulose extinction, indicating probably anorthoclase. The ferro-magnesian mineral is sparsely represented in No. 98, and in the Bruthen type. It is partly chloritized, but in the former it is green hornblende, and in the latter it appears to be a greenish brown biotite. No analyses have been made of these rocks, but it is probable that they would correspond fairly closely with

that of Gabo Island, falling therefore into the group of Victorian alkali granites in contrast to the more calcic type of the granodiorites. An analysis of the Gabo Island granite is included in the table for general comparison with those of the quartz-porphyrites of the Tara Range, and the similarity chemically is very noteworthy.

With regard to the Snowy River Porphyries generally, much more field work combined with chemical and petrological research is necessary before any satisfactory conclusions and generalisations can be made concerning many interesting petrological problems in this area. It is a region which offers splendid scope for future research, and it is perhaps remarkable, as Professor Skeats has already observed, that the late Dr. Howitt having done such valuable preliminary work in this series, never returned to it. Fortunately, the collection of his rocks and thin slices, together with his field notes, are in the possession of the University of Melbourne, and it has been of considerable help in connection with certain petrological points, to be able to compare my own slides with some of those of Howitt's from adjacent areas.

It is clear, however, that compared with the very careful detailed work, both chemical and petrological, given by Howitt to such areas as Noyang, Swift's Creek, Omeo, etc., this region received very scanty petrological attention, and most of the slides would seem to be among some of his very earliest work in this direction, and are often too thick or too much altered for very satisfactory determination.

One of the most interesting points, brought out as my own petrological study of these rocks proceeded, was the predominance of triclinic felspar among the phenocrysts of the acid porphyritic rocks, especially as Howitt had emphasised the reverse, namely, that monoclinic felspars prevailed. On referring, therefore, to the particular slides, which he had mentioned in this connection, it was clear that these early determinations of his required some correction and qualification for all the identifiable phenocrysts were certainly plagioclase. On account, however, of the decomposed state of the rock, some of the felspars were too kaolinized for determination. An important point, therefore, is raised, as to whether this feature concerning the felspars applies to the porphyries of this series as a whole. If so, then it may be possible to distinguish petrologically between these and certain other porphyries, macroscopically similar, but belonging to the Upper Palaeozoic of the Wellington Series.

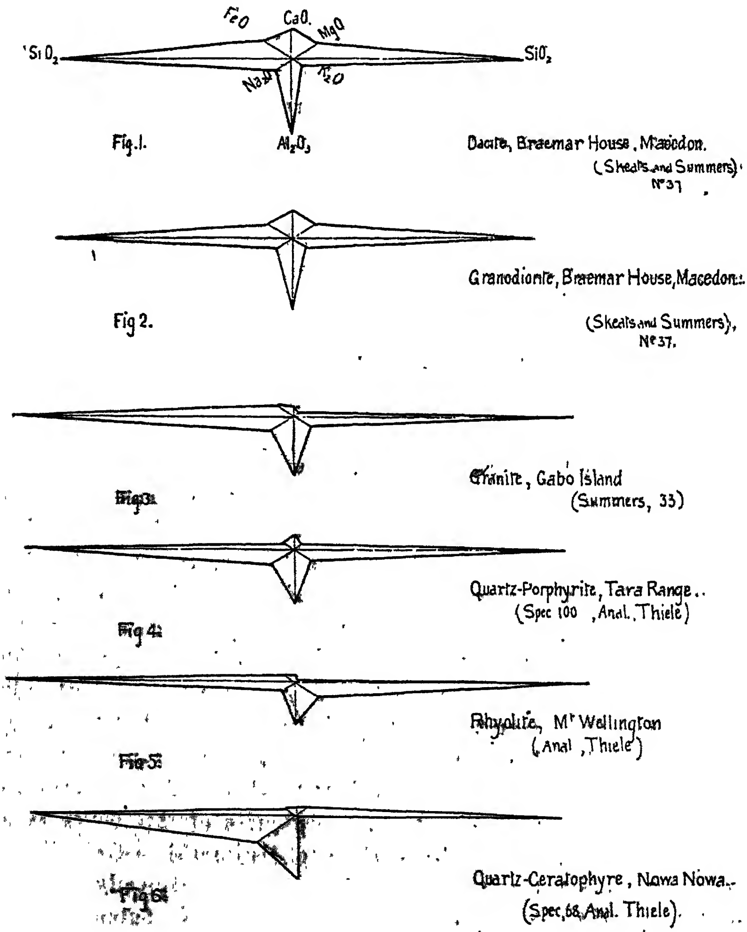
Here again, however, many more sections require to be examined in order to determine whether in their case, as it would seem to be, the orthoclase felspar predominates.

Chemical Characters and Petrographical Relationships.—Only a few analyses are available, and from a limited area. These are all of the acid rocks; none have yet been made of the andesitic types.

Making use of the instructive variation tables given by Summers (33, Fig. 3, p. 270), it is seen that the important types of Devonian

N° 8.

BROGGER DIAGRAMS



igneous rocks, plutonic and volcanic, conform closely to the graphs with the Dacites at the least acid end, and the granites of Gabo, Woolamai, etc., at the other end.

The quartz porphyrites of the Tara Range are found to occupy a position corresponding very closely with that of the Gabo Island granite, and as has been shown petrographically, it is with a granite of this type that they appear to be associated.

It would appear, therefore, that the acid rocks of the Snowy River Series belong to an acid alkali province, in contrast to the acid sub-alkali province, to which the dacites and grano-diorites belong, but all conforming to a normal variation curve.

It would be further interesting to consider the position and relationship of the andesites, but these rocks are much altered and decomposed, and so far, no specimens suitable for analysis have been obtained.

It is worthy of note also that porphyries and rhyolites of the Wellington Series form again a more acid series than those of the Snowy River.

	1	2	3	4	5	6	7
SiO_2	72.55	73.41	71.68	70.51	72.41	72.39	72.49
Al_2O_3	11.74	12.30	13.57	14.36	14.38	14.42	13 48
Fe_2O_3	2.54	2.09	1.28	0.33	2.94	0.56	1.16
FeO	0.46	2.13	1.94	1.95	0.85	0.30	2.09
MgO	0.68	0.14	1.37	1.08	1.18	1.85	0.49
CaO	1.85	1.08	1.88	2.98	0.87	0.85	1.31
Na_2O	3.46	3.71	2.22	3.17	6.86	5.93	3.38
K_2O	4.41	4.04	3.87	3.15	0.13	1.23	4.06
H_2O+	0.41	1.51	1.24	1.18	0.67	1.13	0.76
H_2O-	0.06	0.10	0.29	—	0.04	—	0.18
CO_2	1.80	—	0.08	nil	nil	—	tr.
TiO_2	0.175	0.16	0.33	1.20	0.26	—	0.46
P_2O_5	0.14	tr.	0.03	0.12	0.17	tr.	—
NiO	—	—	—	0.08	—	—	—
MnO	—	—	0.13	—	0.09	0.01	0.13
	100.27	100.67		100.11	100.85	98.67	99.99

1. Quartz Porphyrite, No. 100, Mt. Tara Range.
—Analyst E. O. Teale.
2. Quartz Porphyrite, No. 105, Mt. Tara Range.
—Analyst E. O. Teale.
3. Quartz Porphyry, Federal Territory.
—Analyst A. G. Hall.
4. Quartz Porphyrite, Violet Town, Strathbogie Range.
—Analyst G. Ampt.
5. Quartz Ceratophyre, No. 68, Nowa Nowa.
—Analyst E. O. Teale.
6. Quartz Ceratophyre, Navigation Creek, Noyang.
—Analyst A. W. Howitt.
7. Granite, Gabo Island.
—Analyst J. Watson.

Economic Minerals.—The following minerals are known to occur in the rocks of this region :—

1. Gold.
2. Copper Pyrites.
3. Argentiferous Galena.
4. Iron minerals (Hematite and Limonite).
5. Manganese Minerals (Pyrolusite, etc.)
6. Barytes.

Most of the mining has been done in connection with gold. With most of the others only a few shallow excavations, with an occasional shaft have been opened up. Very little can be said with regard either to their geological occurrence or economic possibilities, for the reason that most of the shafts are inaccessible, and in other cases the opening up has been far too limited to enable any reliable opinion to be formed.

The position of these occurrences is shown on the map. Hematite would appear to be chiefly if not entirely restricted to the "Snowy River Porphyries." Two forms have been noted, a micaceous variety, widely distributed in the southern portions, and a massive hematite. The largest outcrop of this nature was at locality Fe 20, about six and a quarter miles north from Nowa Nowa.

Analyses of some of these ores are given in some of the Annual Reports of the Mines Department, some of them indicating ore of good quality, but insufficient work appears to have been done to determine even approximately the quantity of ore available. The same observation holds with regard to the manganese ores. These occur at the northern end of this region (Loc. M, Specimen 104), and are at the junction of the porphyry, with the overlying limestone series, and from the material exposed in the dump it would appear that they occur in the calcareous and ferruginous shales associated with that series.

Barytes is widely distributed in the porphyry, and is very common in the hills close to Beechers, Canni Creek, where there are a few shallow excavations. Most of it is iron-stained, but some good white material can be seen at Ba 11. (Specimens 13 and 74.) A small open cut here shows an irregular occurrence of Barite in thin veins and small masses replacing the decomposed porphyry.

Argentiferous galena occurs both in the limestone series and in the porphyry. Some prospecting work was in progress at the "Tara Crown," during the time of my visit, where there appeared to be a well-defined fissure lode traversing decomposed felsitic rocks in a N.N.E. direction.

Locality A, 19.—Yellow Water Holes Creek is the position of the long-abandoned "Good Hope Silver Mine." The shaft here penetrates calcareous fossiliferous middle Devonian shales.

Middle Devonian.

The Limestone Series.—Very little time was devoted to this series. An important area, however, composed of these rocks, occurs in the northern portion of this region, and is continuous with that in the vicinty of Buchan. The general features of these rocks have been well described by Howitt (3, 4 and 5), and the age is definitely fixed by the fossils as Middle Devonian.

Associated with the limestones are calcareous shales, and the whole series is in general gently folded, though some instances of high dip are to be noted. Howitt described these limestones as being laid down in troughs and basins in the Snowy River Porphyries, into which they have in many cases been further let down by trough faults. General erosion of the present cycle, and probably also that of an earlier period acting unequally on the limestones and surrounding porphyries has resulted partially in developing important basins, more or less conciding in position with some of those of Palaeozoic times in which the Middle Devonian limestones were laid down. Two basins of these types occur in this region. One is the wide, flat valley of the Ti Tree Creek, surrounded by ridges of porphyry and older rocks, save on the northern side, and the other is a narrower valley to the west, that of the Yellow Water Holes Creek.

It is interesting to note that small residual Devonian limestone occurrences outcrop in both these valleys partly buried beneath gravels sands and clay of late Kainozoic age. These are represented in Section 9. The trough faulting is assumed as probable from general considerations.

It is on the southern end of the large limestone area on a branch of the Tara Creek, in Mr. A. McRae's property, that the new Commonwealth Marble Quarry is situated.

Kainozoic.

These deposits are of considerable interest in that they throw some light on physiographical cycles preceding the present one. Their features will only be briefly referred to here. They are broadly divisable into three groups—

(a) A lower series of marine beds.
(b) An upper series of fluviatile beds.
(c) Basalt.

Both (a) and (b) are to be seen in some fine sections in the cutting of the new Bairnsdale-Orbost railway line.

The Marine beds so far noted consist of cream coloured sandy limestones and marls similar to the Bairnsdale Series, and probably Janjukian in age. These deposits can be traced from the coast to the head of Lake Tyers, where they are ferruginous, but further south along the lake cliffs the characteristic limestones are well developed. Several small outcrops are exposed in the railway line between Nowa Nowa and the Snowy River. But it is at the latter locality along the cliffs overlooking the river flats from the western side, that the finest sections are exposed. The railway cuttings here reveal cream coloured horizontally bedded limestones underlying heavy fluviatile gravels and beds of water-worn boulders.

The various sections have not been closely studied in order to determine whether or not the later marine beds of Kalimnan age are represented, but there are some coarsely bedded ferruginous grits, probably of shallow water marine origin, which may belong to this series. They appear to be unconformably overlaid by the later fluviatile beds.

So far as is known, all the marine beds in this region occur at less than 200 feet above sea level, and do not extend inland more than about twelve miles in a straight line from the coast. This limit approximately marks the position of the early Kainozoic coast line, and corresponds closely to the southern margin of the Highlands in this region.

Fluviatile Deposits.—These overlie the uppermost marine beds, and are therefore late Kainozoic, but as no fossils have been found in them, their age cannot be definitely fixed. They are generally regarded, however, on physiographical grounds as representing an important Pleistocene cycle of erosion. It is almost certain though, that some of these deposits are older, particularly those which occupy ancient drainage lines in the Highlands, beneath lava flows of basalt. In general, however, most of these fluviatile deposits may probably safely be regarded as Pleistocene.

They form an extensive superficial sheet of material, ranging from fine gravels and sandy clays to deposits of large water-worn boulders, the latter providing a very interesting miscellaneous collection of igneous and sedimentary rocks, among which various kinds of porphyries are abundant. They range in height from fifty to several hundred feet above the present river beds, and are found rising in the southern portion of the highlands to at least 800 feet above sea level.

They are to be correlated with a very general period of great fluviatile activity in Pleistocene times in Australia.

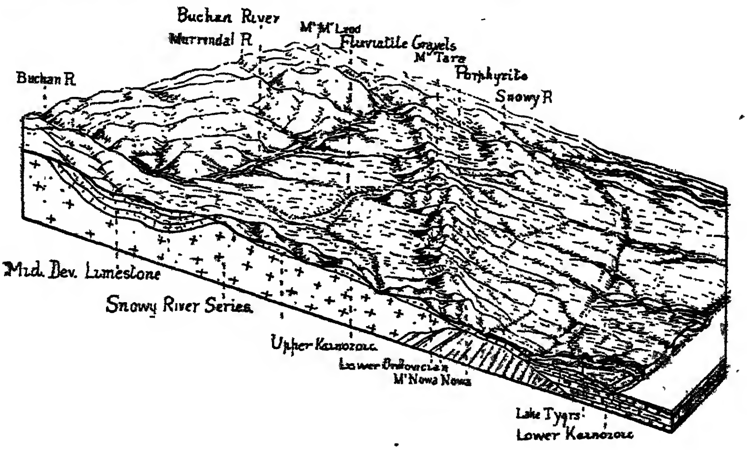
Immediately to the west of the Tara Range in the northern part of Map 4, there is an extensive basin drained partly to the south by Ti-Tree Creek, and to the north into the Buchan River, by the Tara Creek. (See Block Diagram, No. 10.) Remains of a partly-denuded sheet of Upper Kainozoic sands, grits and gravels are here preserved at altitudes rising to about 800 feet above sea level, and resting on a floor varying from Ordovician sediments to Devonian porphyry and limestone.

In general, however, they would appear to have filled in a basin corresponding in position to an ancient Devonian one, in which the Middle Devonian limestones were laid down, almost entirely burying them. Erosion of the present cycle has again partly laid bare the limestones, especially in the basin of the Tara Creek.

Basalt.—This rock has been observed only in the north-western corner of this region, in the vicinity of South Buchan, while passing along the coach road to Buchan, but its extent and character have not been observed. It is most probably to be correlated with the basalt referred to by Howitt, as occurring at Gelantipy and the Buchan River, further north, and classed by him as "Newer Volcanic."

Palaeozoic Earth History.

From the descriptive sections now concluded, dealing with two widely separated areas in Gippsland, which, however, are but very small fragments of the whole region, it will be seen that the Palaeozoic history provides a long succession of events, full of interesting structural, petrological, and other problems about which, however,



our knowledge is so fragmentary that at the best, our ideas can only be largely conjectural. It may, nevertheless, be stimulating to further research to attempt to formulate some picture of the earth history of this ancient era.

It will be seen that the same area along the Mansfield-Wellington belt, marks the site successively of marine deposition in Upper Cambrian, Upper Ordovician and Silurian times, with probable intervening periods of sub-aerial denudation. The Cambrian rocks also indicate contemporaneous volcanic action of a basic nature, the extent of which is unknown. Devonian times were ushered in with the outbreak of great igneous activity, the greatest volcanic period of Palaeozoic times in this part of Australia. Rocks of this age, however, are better developed in certain other parts of Victoria. This region was then mainly a land area, for the volcanic accumulations appear to have been almost entirely sub-aerial. Whether marine conditions supervened here as they did along the Snowy River belt is not known, for no Middle Devonian limestones have yet been recognised, but in late Devonian or early Lower Carboniferous times, a large trough, at least 100 miles long and possibly fifty miles wide was developed and occupied by a fresh water lake. The early lacustrine sedimentation which was thus initiated was accompanied in its early stage by energetic volcanic activity, both effusive and explosive, and of a highly acidic nature. Long after this rhyolitic outburst had ceased, and as deposition proceeded, there were successive outpourings of basic lavas, mostly of no great thickness, and these in turn became covered with later sediments belonging to the same period.

The succession along the Snowy River is less complete. No Cambrian, Silurian, or Lower Carboniferous sediments are known, but the volcanic accumulations of Lower Devonian times indicate very great igneous activity, which was succeeded by marine invasion in Middle Devonian into basins and troughs in the "Snowy River Porphyries."

The history recorded in these zones implies a sequence of powerful earth movements of various kinds to be discussed later. Even a casual look at the geological map of Victoria reveals a general subparallelism of the Palaeozoic formations, with a prevailing northly trend, and a little closer investigation indicates that certain belts have had a more varied history, therefore implying zones of greater unrest or instability, along which movements, also in some cases, igneous activities, have been periodically repeated. It has been

shown that the Mansfield-Wellington belt has had a particularly varied history, and it contrasts strongly with the belt to the east, which is almost entirely Upper Ordovician, and which we may call the Dargo-Ovens zone. To the west, on the other hand, the rocks are chiefly Silurian, overlying Upper Ordovician. With regard to the eastern limits of this area, it is perhaps significant that it corresponds closely with the Cambrian outcrop in the Wellington district, and also the Howqua-Mansfield and Dookie localities farther north, in the vicinity of which rocks doubtfully referred to as the Heathcotian Series occur; while on the western side forming the boundary in part, between a Lower Ordovician region to the west, there is the important Mt. William-Colbinabbin line of Heathcotian rocks. These boundaries, or geological frontiers, may, therefore, represent certain critical lines in the past earth history, along which the struggle for mastery between conflicting earth forces has been repeatedly renewed and fought out.

Successive Distribution of Land and Water.

In considering the probable distribution of land and water throughout Palaeozoic times, we can only be guided by the known outcrops of the various formations, and fresh discoveries at any time are liable to modify our views, but the sub-parallel arrangement and the restriction of particular formations to certain belts or areas strongly suggest a successive alternation of land and water, which might be brought about by a long continued progressive wave-like undulation of the earth's crust.

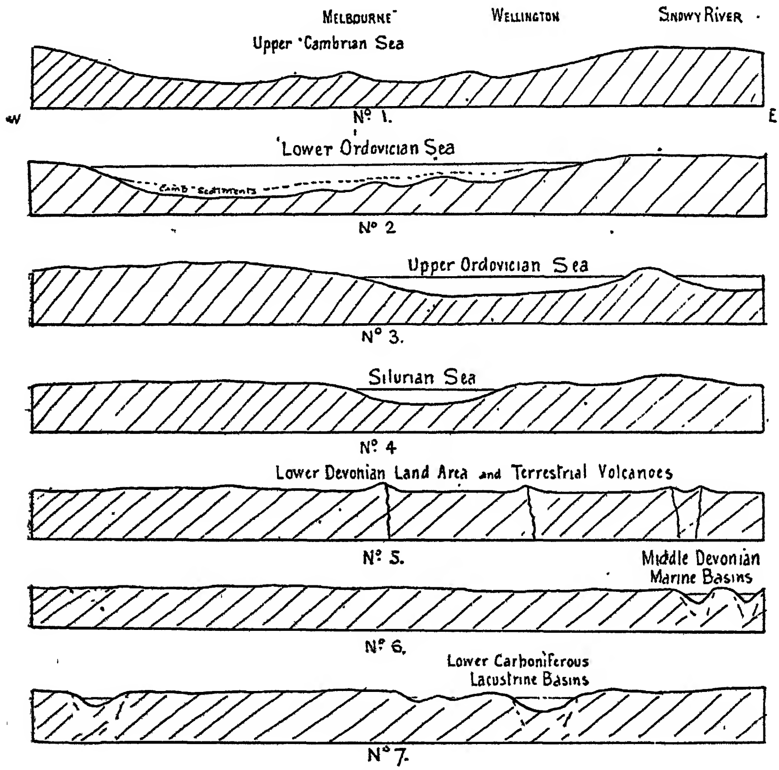
If we consider a succession of east and west sections through Victoria during the Palaeozoic history, representing them diagrammatically to show the relative position of land and water, certain interesting features are brought out. (Diagram No. 11.)

With regard to the Cambrian times, our knowledge is far too fragmentary to enable us to form any reliable conception of the area of the sea of that period, but the pre-Cambrian rocks of Western Victoria may have formed the western limit, while on the east it may have been the belt of crystalline rocks of the Omeo zone, though there is some doubt as to whether these rocks are really Archaean or altered Ordovician.

At any rate, a probable view that seems reasonable would represent a wide Cambrian sea, occupying the greater part of the now dry land of Victoria, with ancient land masses in the east and the west (Diagram No. 11, Fig. 1).

Practically all the Cambrian rocks of Victoria so far known represent accumulations of submarine volcanic material of the nature of

basic lavas and tuffs, the latter often admixed in part with fine normal sediment. The nature of the deposits, while not suggesting specially deep-water conditions, would favour the view that they accumulated over a sea floor at some distance from a shore line. The cherts and tuffs are of a uniform and fine nature, possessing none of the special features expected in those deposited under lit-



Nº 11.
Diagram of Successive Palaeozoic Basins

toral conditions. The advent of Ordovician times does not appear to have been marked by any break in deposition, but the sediments, still of a fine uniform nature, became more normal, for submarine volcanic activity had come to an end. The distribution of land and water remained much the same, and the succession on the whole, therefore, is probably a conformable one, but local gaps in the record appear to occur, notably in the Wellington area, where Upper Cambrian is in contact with Upper Ordovician. Elsewhere —as at Lancefield and Heathcote—it is impossible to determine closely where Cambrian ends and Ordovician begins.

The existing geological map of Victoria shows a striking restriction of Lower Ordovician rocks to a region lying to the west of a line approximating to the meridian of Melbourne, which would suggest an important contraction of the sea at the close of Cambrian times. Later investigations, however, indicate that this is more apparent than real.

Prof. Skeats (40) has shown that a large area in the Mornington Peninsula, originally regarded as Silurian, must now be included in the Lower Ordovician.

Several inliers of Lower Ordovician rocks are now known in the heart of the Silurian region as far east as the Mansfield district, approximately ninety miles to the east of the Melbourne meridian, and as very large tracts of the mountainous country in the eastern highlands of Victoria are very imperfectly explored geologically, it is probable that other occurrences may be revealed in the future. It is unsafe, therefore, in the light of our imperfect knowledge to generalise too positively on the distribution of land and water in early Palaeozoic times. In general, however, it would appear that there was a progressive restriction of the marine basin through Lower Palaeozoic to the close of Silurian.

In the sections therefore (Diagram 11), the relative position and extent of the successive basins are merely represented tentatively, summarising our existing knowledge of the palaeogeography of this region.

In Upper Ordovician times a marked narrowing of the Palaeozoic basin appears to have taken place, for no Upper Ordovician rocks have yet been found to the west of the Melbourne meridian. The sea may have then occupied two basins partly separated by the Omeo crystalline belt. (Diagram 11, Fig. 3.)

The next event was again a considerable restriction of marine area, drawing the Silurian Sea into a central basin corresponding to the western part of the Upper Ordovician Sea. It is not clear whether complete land conditions intervened before the Silurian Sea reoccupied the site of the western portion of that of the Upper Ordovician. The evidence of uncoformability is not conclusive everywhere. (Diagram 11, Fig. 4.) The advent of Lower Devonian times was marked by the disappearance of marine conditions altogether, and the outbreak of extensive terrestrial volcanic activity, accompanied also by widespread plutonic disturbances and earth movements. The dacites, porphyrites, granodiorites, and "Snowy River Series," and possibly also the normal granites belong to this

period. The sea never again transgressed in Palaeozoic times to the extent of the early marine basins. (Diagram 11, Fig. 5.) In Middle Devonian times, the last marine deposits were formed in the restricted basins or troughs in Eastern Victoria, which were depressed below sea level, and were partly filled by limestone and calcareous shales.

The region of the depression coincided closely with that occupied by the volcanic zone of the Snowy River Series (Diagram 11, Fig. 6). The conditions of late Devonian and early Carboniferous were essentially terrestrial, but were accompanied by the development of several lacustrine basins, the greatest of which was the great Mansfield-Wellington trough, and as previously indicated, the early sedimentation was accompanied by rhyolitic effusions, and, later, by basic lava flows. (Diagram 11, Fig. 7.)

Types of Earth Movements.

The general trend of all these Palaeozoic basins appears to have been northerly, and the type of crust movement which most reasonably explains the succession of basins, parallel, but laterally shifted or restricted, is the conception of a slow wave-like undulation of the earth's crust, the basin being reciprocal feature of the adjacent land mass. It is possible to picture a prolonged progressive movement of this type to proceed with or without marked compressional or tangential movement. In the first case, the beds of each successive formation would become highly folded, and in the latter only slightly so. The idea does not preclude the possibility of periods of a much augmented rate, with important fractures and displacements.

An alternative view would be to consider the formation of a succession of basins such as here described, as being due mainly to the differential movement of great blocks or earth segments along fault planes, certain areas being alternately lifted and lowered. The whole structure of the Palaeozoic rocks, however, favours the first view, but it does not exclude the possibility and even the probability of a certain amount of faulting and block movement as well, and it would seem that as the Palaeozoic era drew to a close, after the great Devonian convulsion, though the fold movement still predominated, that of the block type became more pronounced, and finally prevailed throughout Mesozoic and Kainozoic times.

If the regional distribution of calcic and alkali igneous rock is definitely related to fold and fault movement respectively as Harker has contended, then in areas where both these types may have acted

either successively or simultaneously, it would be reasonable to expect complex and apparently anomalous results with regard to the associated igneous activity. Summers (33) has reviewed the relationships of igneous rocks to earth movements in Victoria, and has opened up an extremely interesting, but very debatable subject. He has, however, shown that it is impossible to apply Harker's generalisation. It is practically certain that if the various geologists who are sufficiently familiar with the local geology were to attempt to make out a picture of the Palaeozoic history with special reference to the associated earth movements, they would differ considerably in important details. One or two events, however, stand out very clearly, and it is probable that all would agree with the view that the opening of the Devonian epoch was marked by most energetic earth folding, which intensely crumpled all the already folded pre-existing formations.

As Summers pointed out, the dominant movement was of the pacific type along north and south fold lines, but was it accompanied by great volcanic and plutonic activity, as has generally been believed? It would rather appear that the igneous phase, though related with this great crustal disturbance, lagged behind somewhat, otherwise, we might reasonably expect to find a definite linear arrangement or relationship of the igneous rocks, with some of the major fold lines. This is far from the general rule, however, in fact it is only in the case of the "Snowy River Porphyries" that a meridional arrangement is apparent. All the other occurrences appear to be distributed in a very irregular manner. Further, the volcanic deposits would appear to rest unconformably on the upturned edges of the older rocks. It appears to be the exception that the ash beds are intensely folded with the older beds.

Summers (33) has also discussed the question of the Heathcotian diabases and earth movement, and favours the idea that the basic eruptions and submarine tuffs of the Heathcotian Series are more easily explained as accompanying fault action rather than fold movement. It must be admitted, however, that the evidence is very scanty and indefinite, and is open to be interpreted in either way. The area exposed is far too limited, and the structure too imperfectly known to enable any satisfactory criticism to be made.

The Granite Batholiths and their Relation to Palaeozoic Structure.

No account of Palaeozoic history would be complete without some special reference to the abundant granite masses which penetrate the Lower Palaeozoic sediments.

Petrologically, they fall into two groups—(1) the sub-alkali group of granodiorites, (2) the group of alkaline granites. Regarding their age, they are here on petrological grounds all considered as Lower Devonian, but the alkaline granites have been sometimes referred to as probably older, mainly because they have nowhere yet been noted intruding Silurian sediments. All attempts so far to correlate the occurrence and distribution of these rocks with definite structure lines have been unsatisfactory.

The various masses are very irregular, both with regard to outline and distribution. When elongate or elliptical in shape, their longer axes just as often as not, are at right angles to the fold lines of the ancient rocks. Their contacts have not been exhaustively examined, but in many of the important instances they truncate the strata they invade, and no satisfactory linear or other distribution of the various outcrops has been recognised.

Professor Gregory, in his Geography of Victoria (34), attempted to link up certain granite masses to form the roots of what he termed the Primitive Mountain Chain, having a general east-north-east trend; and a still more fragmentary line to the south, more or less parallel, he named the Bunurong Range.

The grouping of the granite areas in this way appears to have little to support it, even from a linear arrangement, and far less from any structural consideration, as T. S. Hart has already pointed out (35).

Howitt (32) long ago recognised the importance of the factor of the assimilation of sediment and other rocks by a plutonic magma, a view which has received special emphasis and elaboration more recently by Daly.

This idea has received some support with regard to Victorian granite and allied rocks, from the observations of Howitt (32), Hart (35), Skeats and Summers (27), and Junner (38).

The petrological evidence in support of the idea is still very scanty, but structurally and otherwise it seems to provide the best conception of the great development of granite batholiths and their distribution in Victoria.

Pitch Along Anticlinal Lines.

This structural feature is one of great importance in the consideration of Palaeozoic geology in Victoria. Every area that has been closely studied has emphasised the importance of its bearing on the general structure, and it frequently also demands careful consideration in connection with the development of mining operations on the gold fields. The systematic work of the Geological Survey has added much to our knowledge concerning this feature in

practically all the important goldfields, but little is known with regard to it in most other regions.

There are various questions which arise when it is made a subject for careful consideration, and two of these perhaps, stand uppermost—

(1) The age or geological epoch, when it was impressed upon the Palaeozoic formation.

(2) The dominant factor or factors contributing to its development.

Very few opinions have been expressed concerning this subject.

The late Dr. T. S. Hall (39) apparently associated its development with the movements which led to the uplifting of the existing highlands and formation of the Main Divide. This would imply a very late Kainozoic age. Its direction, however, appears to be too inconsistent and variable to be associated fundamentally with a movement which was essentially that of block movement.

T.S. Hart (35) has discussed the question and suggests a number of probable causes which are worth tabulating :—

(1) The making and dying away of individual folds.

(2) Local disturbances as a fault affecting a small area.

(3) Varying intensity of folding from place to place.

(4.) Transverse folding, simultaneous or subsequent to the main folding.

(5) Settlement of an imperfectly supported area over an invading granite.

(6) Subsequent tilting or transverse warping of folded blocks.

The above factors are all clearly competent to produce the results under discussion, and when it is considered that they may all have repeatedly contributed towards this end through past geological history, it becomes a complex problem to endeavour to apply anything approaching a definite statement with regard to its age and origin.

Hart, however, would apparently restrict the main period of development to Palaeozoic times, and this is a view most consistent with general tectonic considerations. It is unsafe to lay down any hard and fast conclusions with regard to this feature generally; each area will have to be considered carefully in detail with due regard to local and general tectonic disturbances, but one cannot help being impressed with the possible favourable conditions produced by the great batholithic disturbances of Devonian times, especially if Daly's conception of magmatic stoping and associated down-

warping of overlying areas be regarded as the most favourable explanation of the mechanism of such an important petrogenic phase in earth history.

The Relation of the Dyke Rocks and Quartz Reefs to Structure and Earth Movements.

It has long been recognised in Victoria that many of the important gold-bearing reefs can be grouped along certain more or less parallel zones, with a northerly trend, and separated by other belts of non-productive reefs or marked by the absence of reefs altogether. Most of the Victorian reefs (excepting the Bendigo and Castlemaine fields) occupy definite fissures, or are associated with igneous dykes which have intruded fracture lines. The bearing of these occurrences in general is northerly, parallel with axial lines of folding.

The age of the great reef formation is generally believed to have been Devonian, and genetically associated with the granitic intrusions of that epoch.

One belt in particular, is worthy of mention, illustrating very well the features above mentioned; namely, the Walhalla-Woods Point Zone. The prevalence of dykes, frequently of a diorite type, and auriferous reefs along this zone, is in contrast to their absence in the country to the west and east. Other such instances might be mentioned. There are also non-auriferous zones, where fractures, faults or dykes are common, about which, however, little is known with regard to their age and distribution. Many of these may not be Palaeozoic, and these are therefore not included in the present discussion.

It would appear from the consideration of the above that one phase of the great Devonian tectonic and igneous disturbance found expression in the development of lines of fracture, with a definite northerly trend along certain zones, and their infilling with igneous dykes and quartz reefs. The geological study of these areas has so far not revealed anything to suggest that these fracture lines can be regarded as planes of great differential movement on either side of which important earth blocks or segments were dislocated. They would appear rather to indicate zones of tension due to crustal adjustment, accompanying the folding and batholithic intrusion of that period.

The Fracture Line of the Snowy River Porphyries.

As indicated previously, this zone is the only one where the occurrence of certain igneous rocks other than dykes of the Devonian

period corresponds closely with the general direction of the Palaeozoic trend lines. This arrangement led Howitt to postulate the idea that the volcanoes of this epoch were disposed along a meridional fissure, and though the actual position of the sites of these ancient volcanic vents still remains to be located, the view certainly offers the most probable explanation of the features as a whole.

This zone would appear also to have been successively fractured at later periods. The occurrence of the iron ores appears to be associated with one of these lines. The marked shearing resulting in the production of porphyroids is another phase, and the origin of the basins in which the limestones occur, though perhaps referable mainly to warping and erosion, may possibly be associated also with some trough faulting. Howitt has also referred to certain persistent features along the eastern side of the Snowy River Porphyries, coinciding with the valley of the Snowy River, suggesting the existence of a powerful meridional fault. Other parallel faults coinciding with the Limestone Creek and Buchan River are also suggested. (3, p. 189.)

The age, however, of these fault and fracture lines, and, in fact, their exact position also, is very indefinite. Some may be post-Palaeozoic, and it is even probable that if not originating in Kainozoic times, the plateau building period that produced the existing highlands has caused renewed movement along some of these major faults.

The undulations and gentle folding of the Middle Devonian limestones show that the fold movement, though less intense than in earlier times, still continued, and the same feature is shown by the structure of the Upper Palaeozoic rocks of the Wellington region.

Summary.

The principal features to be emphasised as a result of the consideration of the areas under discussion may be briefly enumerated as follows.—

1. *Wellington District.*

(1) The general structure of the Wellington-Dolodrook region is anticlinal, passing from a broad, simple fold in the case of the uppermost rocks to complex repeated folding in the case of the underlying old rocks.

(2) The periods of folding have been renewed from time to time, possibly on four successive occasions, but the trend of all the fold lines has persisted in a tolerably constant direction, varying between north-west and north-north-west.

(3) Denudation of the existing cycle has developed to such an extent that a complex inlier is exposed, consisting of a core of Cambrian rocks enveloped successively by Upper Ordovician, Silurian and Upper Palaeozoic sediments.

(4) The Upper Palaeozoic strata are of lacustrine origin, and those of the other periods are marine. The Cambrian limestones have yielded a definite series of trilobites, and are interbedded in basic tuffs. The Upper Ordovician rocks are black slates, chertified in part, and they contain abundant typical graptolites. The Silurian rocks have so far only yielded crinoid remains.

(5) Igneous activity is represented in two and probably three, distinct periods if we consider the district as a whole, including the Upper Palaeozoic rocks as far as Mansfield. The Cambrian series contains a pre-Upper Cambrian serpentine, with chromite and corundum derived from peridotite and pyroxenite rocks, and the Upper Cambrian contains basic tuffs. Volcanic rocks of the nature of porphyrites allied to dacites occur in the King River Valley, and others, mainly of an andesitic nature, on Fullarton's Spur, in the Macallister Valley. These are probably Lower Devonian. The basal portions of the Upper Palaeozoic (Lower Carboniferous), contain thick beds of rhyolite, and acid pyroclastic deposits. Higher up in the series there is a succession of basaltic flows (melaphyres) interbedded with the sediments.

(6) Special structural features are noted along the Macallister valley, where the Upper Palaeozoic rocks, normally dipping at a low angle, are here frequently highly inclined, and an important fault line is recognised, approximating in position to that of the Macallister Valley, and bearing, therefore, in a N.N.W. direction.

2. *The District of Nowa Nowa.*

(1) The cherts and jaspers of the region have been examined with regard to age and the origin. All the cherts observed are altered slates, and are regarded as Upper Ordovician. Definite graptolites have been found in some of them. The red jaspers are often associated with micaceous hematite, and are found chiefly in the porphyroid belt of the "Snowy River Series," and are

therefore Lower Devonian. They appear to be metasomatically altered igneous rocks, varying from andesitic to more acid types. Though widespread in their distribution, each occurrence appears to be small in extent.

(2) The oldest sediments in this region are regarded as Upper Ordovician. Definite graptolites were found in four distinct localities, and there does not appear to be any valid reason, structural or lithological, to justify the separation of any of the non-fossiliferous portions from those yielding graptolites.

(3) The igneous series known as the Snowy River Porphyries, is regarded as Lower Devonian, and rests uncomformably on the Upper Ordovician sediments. The chief additions to previous knowledge concerning this extensive igneous belt are:—

(a) The recognition of porphyroids.

(b) Finely stratified ash beds.

(c) The occurrence of trachytic and andesitic rocks.

(d) The fact that the so-called quartz-porphyries are really quartz-porphyrites, triclinic felspar predominating. Two analyses of this type are given.

(e) A soda rich type is described as a quartz-ceratophyre. Both microscopically and chemically it is shown to be closely similar to certain rocks described by Howitt from Noyang, as quartz-porphyrites, and later referred to by Skeats as ceratophyres.

(f) The chemical characters and petrographical relationships of the igneous rocks are discussed, and it is shown that the porphyrites are genetically related to the alkali granites, which are characteristic of this part of Victoria.

Making use of a variation diagram to compare the various acid igneous rocks of Victoria, it is seen that the quartz-porphyrites of the Tara Range, and the alkaline granite of Gabo Island, etc., conform closely to the graphs occupying the opposite end to that of the dacites and granodiorites. It would appear, therefore, that the acid rocks of the Snowy River Series belong to

an acid alkali province, in contrast to the acid sub-alkali province to which the dacites and grano-diorites belong, but conforming to a normal variation curve.

3. Under the heading of Palaeozoic Earth History, the following features are discussed :—

(1) Successive distribution of Land and Water.

(2) Types of Earth Movements.

(3) Granite Batholiths and their Relation to Palaeozoic Structure.

(4) Pitch along Anticlinal Lines.

(5) Relation of Dyke Rocks and Quartz Reefs to general structure and Earth Movements.

(6) The Fracture line of the "Snowy River Porphyries."

A succession of Palaeozoic basins of sedimentation, with a general northerly trend appears to be recognisable. These have varied in position and extent from period to period.

They have overlapped in certain instances, while in others they appear to have been laterally shifted, a land area taking the place of the basin of an earlier period, and vices versa.

The resultant formations have nevertheless a general parallel arrangement.

This succession of basins, parallel, but laterally shifted or restricted, is thought to be best explained by the conception of a slow wave-like undulation of the earth's crust, the basins being the reciprocal feature of the adjacent land mass. The basin would, therefore, be regarded as of the type of a geo-syncline. Block movement, though not excluded entirely, is regarded of minor importance during this era. The most intense folding was pre-Devonian. The great granite batholiths, though belonging to the active Devonian period of tectonic and igneous disturbances, show much irregularity of shape and distribution, and also a discordance with strike and fold lines. It is considered that their features generally are best explained by the conception of "magmatic stoping."

The consequent disturbance of surrounding and over-lying blocks of sediments may have been one of the most important agencies inducing the features of "pitch," so common throughout the Lower Palaeozoic formations. Certain zones appear to have been subjected more frequently during Palaeozoic times to tectonic and volcanic disturbance than other regions.

The Wellington-Mansfield Belt is one of these areas, the zone of the Snowy River Porphyries represents another.

The general trend of both fracture and fold lines throughout the Palaeozoic era appears to have been between north-west and northerly.

Acknowledgments.

In conclusion I wish to express my indebtedness to the following persons:—The late Dr. T. S. Hall for the careful examination of numerous Upper Ordovician graptolites; Mr. F. Chapman, A.L.S., for the identification and description of the Upper Cambrian fossils from the Dolodrook limestone; Mr. H. Herman, Director of the Geological Survey, for the loan of an able field assistant in the person of Mr. J. Caldwell, who accompanied me to the Wellington region on one of my extended excursions; Professor Skeats and Dr. H. S. Summers of the Geology School of the Melbourne University for useful criticism and advice in the laboratory; Mr. W. Thorn, Chief Mining Surveyor, for access to certain mining surveys of assistance for field work; Mr. J. Dunn, of the Lands Department, for frequent advice concerning maps and plans concerning some of the regions included in the field work. Last but not least I wish to include my father, whose untiring and sympathetic help in the field has been extended over many years on numerous excursions in this region.

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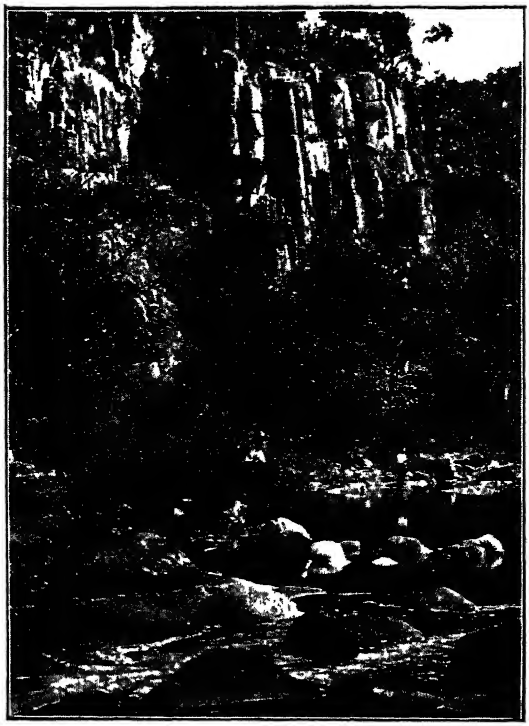
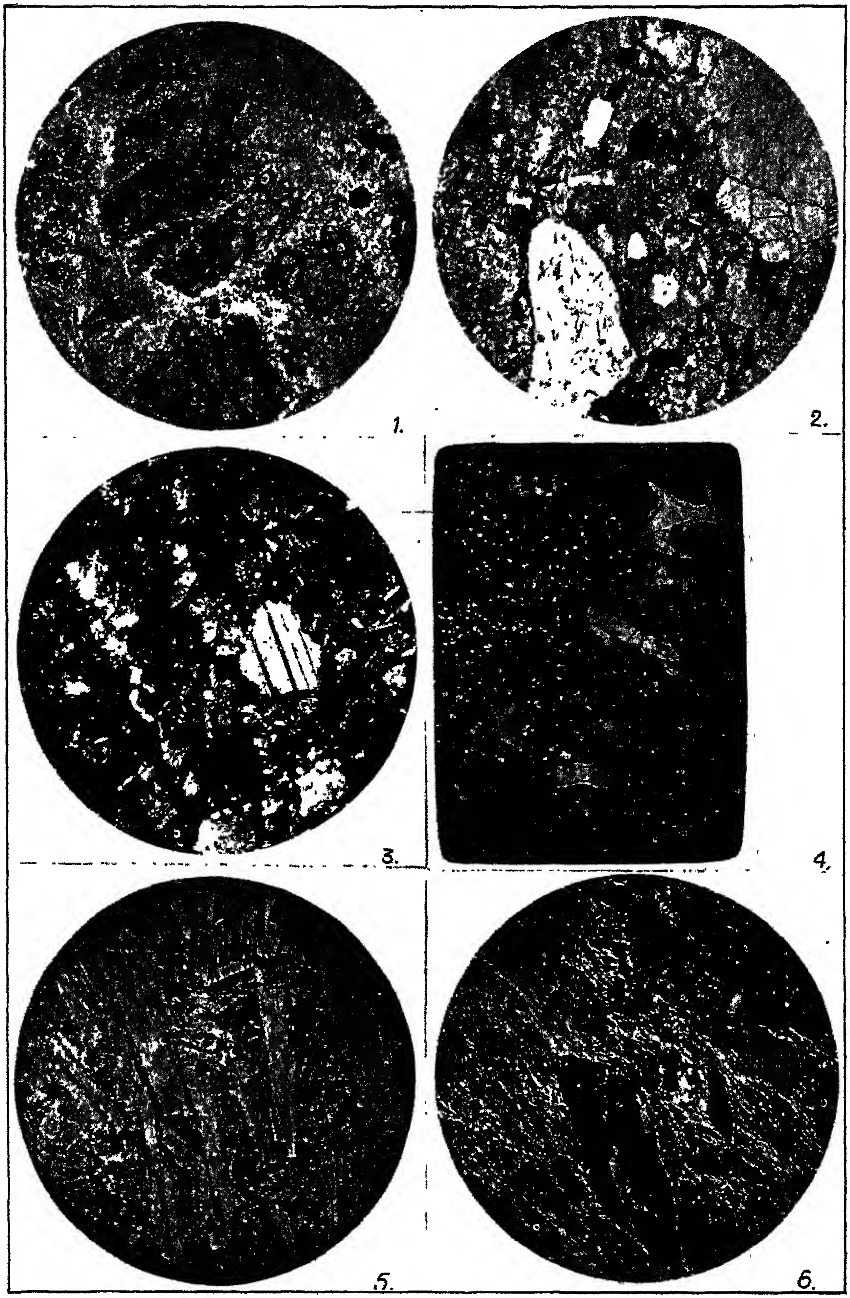
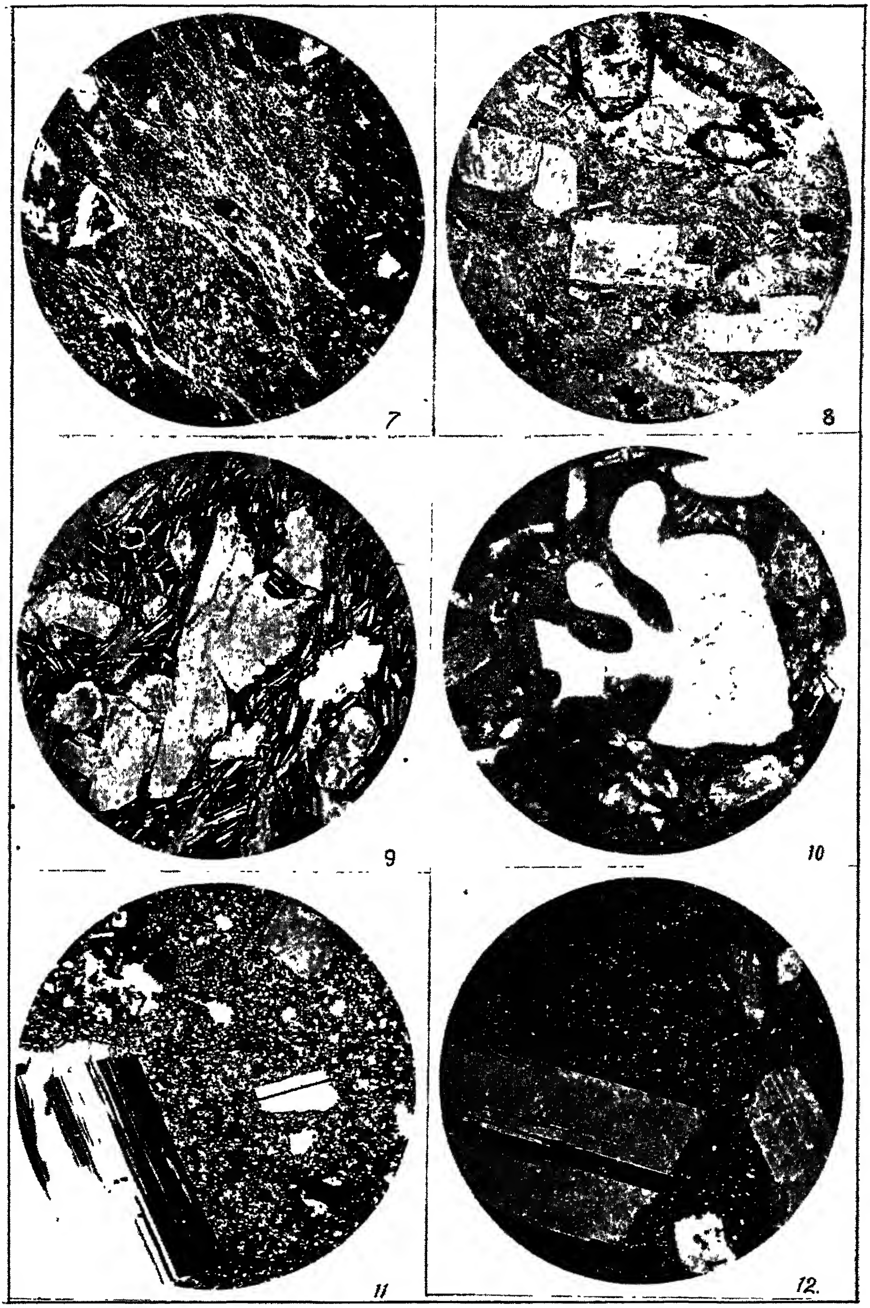


Columnar Rhyolite, Wellington Gorge, and weathered Garvey Gully Tuffs

Overfolding of Silurian, Dolodrook R., and Columnar Rhyolite, Mt. Wellington



Rocks of Mt. Wellington and Nowa Nowa



Rocks of Nowa Nowa and of Mt. Tara (10).

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. IX.—*Note on the Correction for Chronometer Rate.*

By J. M. BALDWIN, M.A., D.Sc.

[Read 14th August, 1919.]

The following very easy way of applying the correction for chronometer rate has been in use at the Melbourne Observatory for some years. As I find that many who have often to use the correction are unaware of the method, it seems worth while, although the method is probably not new, to call attention to it.

Let T be the period of a vibrating system in seconds

T′ the period as shown by a chronometer

r the daily rate of the chronometer, + if losing, so that the chronometer indicates $(86400 - r)$ seconds in a day,

$$\text{and 1 chronometer second} = \frac{86400}{86400 - r} \text{ seconds.}$$

$$\therefore \qquad T = T' \cdot \frac{86400}{86400 - r}$$

$$\text{and } \log.T = \log.T' - \log.\left(1 - \frac{r}{86400}\right)$$

$$= \log.T' + .43429 \times \left\{\frac{r}{86400} + \tfrac{1}{2}\left(\frac{r}{86400}\right)^2 + \cdots\right\}$$

The value of the right hand side is nearly

$$\log.T' + \frac{r}{2} \times 10^{-5}$$

so that, *to obtain log.* T, *add half the daily rate in seconds to the fifth decimal place of log.* T′. The value of T so obtained will be within one part in a million for values of r up to 15 seconds. If a siderial chronometer is used, $r = -236{\cdot}56$, and even in this case the accuracy attained is 1 part in 100,000.

The expression

$$\log.T = \log.T' + \frac{r}{2} \times 10^{-5} + \frac{1}{190} \cdot \frac{r}{2} \times 10^{-5}$$

gives a value of T correct to one part in a million, provided r is not greater than 120, while the addition of the extra term

$$+ \frac{r}{900} \cdot \frac{1}{190} \cdot \frac{r}{2} \times 10^{-5}$$

gives more than sufficient accuracy in every case.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. X.—*A New Method of Determining the Mechanical Equivalent of Heat.*

BY

Professor T. H. LABY, M.A.

AND

J. K. ROBERTS, B.Sc.

(Natural Philosophy Department, University of Melbourne).

(With Plates X. and XI. and 1 Text Figure.)

[Read 11th September, 1919.]

Introduction.

It appeared to the writers that an additional direct determination of the mechanical equivalent of heat would be of value, and might, in view of the progress of precise measurement, attain higher accuracy than that previously realised, and, incidentally, information might be obtained as to the accuracy of the electrical units.

After a long series of preliminary experiments, a method, in which a copper cylinder is heated by a rotating magnetic field, has been devised, possessing the characteristics—(1) of accurately stationary temperatures, and (2) that a small fraction of the heat developed is lost. This method is being carried out so as to attain, if possible, an accuracy of 1 in 10,000 in J, the mechanical equivalent of heat.

Previous Determinations.

There have been five determinations[1] of the mechanical equivalent of heat, to which it is necessary to refer—namely, those made by Joule, Rowland, Misculescu, Reynolds and Moorby and Rispail. Of these experiments only those of Rowland and of Reynolds and Moorby appear to possess high accuracy, and they are not immediately comparable, as the values of J, which they give, are in terms of different heat units. Several determinations have been made of what may be called the electrical equivalent of heat. If the mechanical equivalent, J, were known to an accuracy of 1 in 10,000 (which should not be beyond attainment), the degree of its

1. Joule, Phil. Trans., Vol. CXL. p. 61 (1850); Rowland. Proc. Amer. Acad., Vol. XV., p. 75 (1879); Miculescu, Journ. de Phys., Vol. I., p. 104 (1892); Reynolds and Moorby, Phil. Tran. Vol. CXC., p. 301 (1897); Rispail, Ann. Chim. Phys., Vol. XX., p. 417, (1910).

agreement with the electrical equivalent would be an indication of the accuracy with which the practical electrical units realise their intended values.

Principle of the Experiment.

The method to be described, we believe, has not, been previously applied. Baille and Féry[2] proposed to generate heat, not by stirring water. but by placing a copper cylinder in a rotating magnetic field produced by polyphase currents. Their proposal is open to the objection that the lines of magnetic force would probably have a component of motion in the direction of the axis of the copper cylinder. Heat would then be generated to which there was no corresponding couple. We have obtained a rotating magnetic field with a known and fixed axis, A, by the rotation of an electro-magnet. A copper cylinder is mounted (see Figs. 1 and 2) so as to be capable of rotation about a vertical axis, B, and is

2. Comptes Rendus., Vol. CXXVI., p. 1494 (1898).

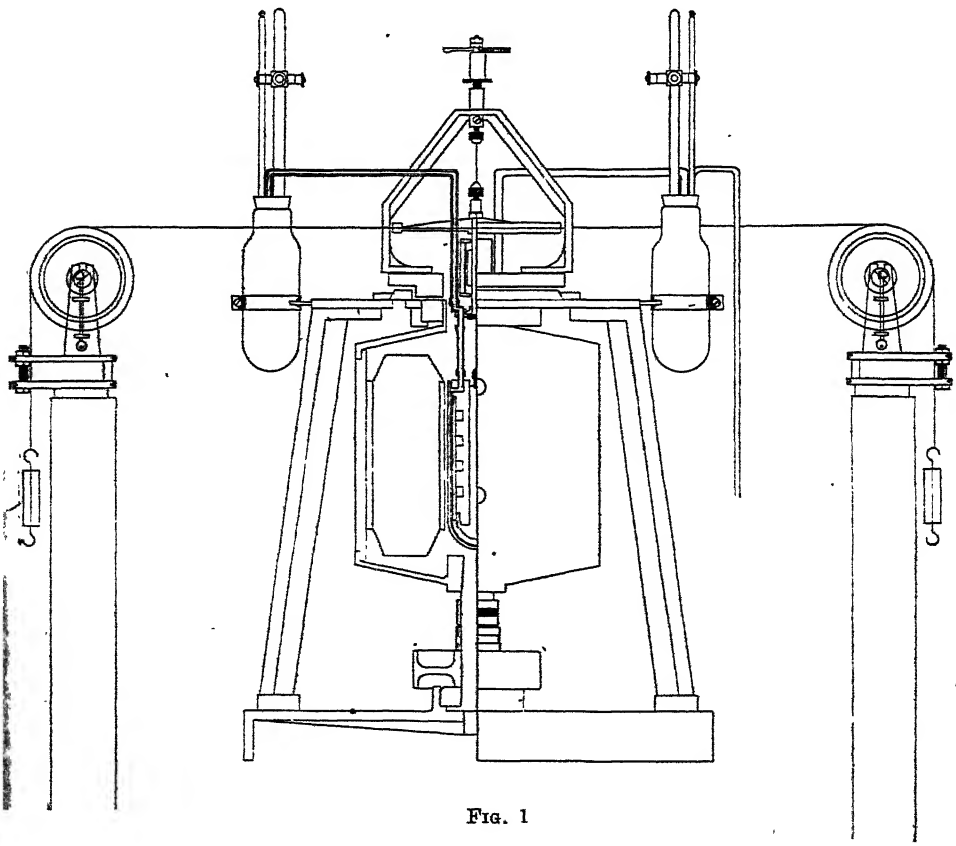


FIG. 1

placed in the rotating field. The axes A and B are brought into coincidence. The determination of J then becomes a question of finding the work done on the copper cylinder, and the heat developed in it. The work is found as in Rowland's experiment. The copper cylinder is attached to a vertical axle and wheel (diameter, D cm); and the whole is suspended by a torsion wire. Two wires pass round the circumference of the wheel over pulleys to two masses of m gm. The couple mgD dyne.cm. produced by these weights balances the couple arising from the rotating magnetic field. The torsion wire gives stability to the system.

The heat developed is measured by a continuous flow method. Water flows past a platinum thermometer, then it circulates round the copper cylinder and out past a second platinum thermometer. The heat developed is $M(\theta_2-\theta_1)$ calorie, where M gm. is the quantity of water flowing in an experiment, and $(\theta_2-\theta_1)$ degree is the rise of temperature. To eliminate the heat losses, L calorie, from the expression for J, two experiments are made—a heavy and a light one—in which the inlet and outlet temperatures θ_1 and θ_2 are the same. The heat developed in the former is about ten times that in the latter. We then have for the heavy experiment

$$\pi Dnm_1g = J(\theta_2-\theta_1)M_1+L$$

and for the light

$$\pi Dnm_2g = J(\theta_2-\theta_1)M_2+L$$

and therefore

$$J = \pi Dng(m_1-m_2)/\{(M_1-M_2)(\theta_2-\theta_1)\}$$

where n is the number of revolutions of the field magnets for the period of an experiment, which is the same for the light and heavy experiments.

The heat developed in the light experiment is made less than in the heavy experiment by reducing the strength of the magnetic field.

In the above relation it is assumed that the loss of heat, L, is constant for a given value of the inlet and outlet water temperatures. The text-book accounts of Callendar and Barnes' experiments[3] lay inadequate stress on the conditions which those observers showed must be fulfilled for this assumption to be justified. In our preliminary experiments the loss of heat, L, bore little relation to the inlet and outlet water temperatures, θ_1 and θ_2. With θ_1 and θ_2 fixed, L would vary widely with the rate of flow of the water through the copper, which was then in the form of a hollow copper ring. After the factors which determined the heat losses in this form of the apparatus had been determined by a number of experi-

3. Callendar, Phil. Trans., Vol. CXCIX., 1902, pp. 112, 114, 115, 122. Barnes, Phil. Trans., Vol. CXCIX., 1902, pp. 224-228.

ments, the apparatus now being described was designed so that the inlet and outlet water temperatures would determine the surface temperatures of the calorimeter, and so for a given temperature of the surroundings of the calorimeter, determine the loss of heat, L, independently of the rate of development of heat in the calorimeter.

The equation we have given assumes that three axes are parallel, namely, the axis of rotation of the magnetic field, the axis about which the copper cylinder is free to rotate, and the axis of the couple produced by the two masses m. This condition is fulfilled to the required accuracy in the apparatus as we are using it.

In another paper,[4] the theory of the electrical device, which we have used in these experiments, is given. It is there shown that the couple ψ dyne.cm. acting on the stator is given by the expression

$$\psi = \pi\rho N\phi^2 / \{ \rho^2 + 4\pi^2\lambda^2 N^2 \}$$

where N revolution per sec. is the speed of the rotor, ϕ maxwell is the flux crossing the copper cylinder, ρ is proportional to the resistance from end to end of the cylinder, and λ cm. is a certain inductance.

Design and Operation of the Apparatus.

It will be convenient to call the rotating field magnets, the rotor, and the copper cylinder and the iron cylinder which it encloses, the stator.

The rotor (see Figs. 1, 2, 3 and 4) is mounted on ball bearings, with its axis vertical. The field magnet windings are connected through slip rings to a lead storage battery. The rotor is belt-driven by a shunt motor, and the speed of the former is determined by means of a worm gear, which, at the completion of every 100 revolutions (that is, about every four seconds), moves a pen writing on a chronograph; the pen also indicates seconds, as given by a standard clock. In this way, the rate of rotation and number of revolutions is recorded.

The rotor is pierced with eight sighting holes (see Figs. 3 and 4) for adjusting the axis of the stator parallel to that of the rotor. These holes, if fully open, thoroughly ventilate and cool the field magnets.

The lower bearing of the rotor is rigidly held by an iron bed plate bolted to a brick foundation. In order to prevent vibration in the plate, which carries the upper bearing of the rotor and the

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4. J. K. Roberts. The Design of a Motor with Large Air Gap and Rotating Field Magnets. Proc. Roy. Soc. Vict., XXXII., 1920, p. 156.

bearing of the stator, the rotor was balanced. Suitably illuminated points situated on the plate in question were observed with a microscope, carried by a support free from vibration, and the rotor was balanced until the amplitude (i.e., diameter of circumscribing circle) of the vibration of the plate was reduced to .001 cm.

The field magnets have two poles, and there are two windings on each pole. These windings can be connected in series so that the turns reinforce one another, and the maximum flux for a given current produced. They are so connected for the heavy experiment. The windings can also be connected in series so as to oppose one another in their magnetising effect. They are so connected for the light experiment. In this way the flux can be reduced to one-tenth without changing the current in the windings and, therefore, without changing the temperature of the rotor in the light and heavy experiments.

The Stator and Calorimeter.—The construction of the stator is shown in Figs. 5, 6 and 7. Fig. 5 shows copper and iron cylinders. The iron cylinder increases the magnetic flux, and supports the copper cylinder. The channels on the external surface of the iron, and the axial hole, carry the water in its circulation through the apparatus. The iron cylinder is attached to a glass tube (see Fig. 6) filled with eider down. in order to reduce loss of heat by conduction. The glass tube in turn is attached to a steel shaft which passes through a ball-bearing, and, at its upper end, is suspended by a steel torsion wire. The wire supports the whole weight of the shaft and calorimeter.

A thin sheet cylinder encloses the copper cylinder, and a Dewar flask encloses the steel, copper, and iron cylinders, which to prevent corrosion are all silver plated.

The water enters the calorimeter (see Figs. 5, 6 and 7) through a rubber tube, flows downwards between the inside wall of the Dewar flask and the thin steel cylinder, turns upwards and flows between the steel and the copper, then down between the copper and iron, and finally out of the calorimeter through the axial hole in the iron armature. The object of this somewhat elaborate circulation is—(1) to bring the water into thorough contact with the copper and iron in which the heat is generated, (2) to break up stream lines, and so ensure that the inlet and outlet water temperatures determine the heat losses of the calorimeter.

The ball bearing which maintains the shaft vertical was very carefully made, and is used without oil lubrication, which was found to increase the friction. The angular amplitude of the stator

when set in torsional oscillation decreases by 10 per cent. per vibration, from which it can be shown that the friction is very small. A mirror is attached to the shaft of the stator, and its movement observed by lamp and scale. With the apparatus arranged for a determination of the mechanical equivalent, the stator oscillations are not critically damped; frictional resistance arising from the viscosity of water is added, till the damping is critical.

Couple.—Two thin wires (see Fig. 1) pass from the circumference of the wheel over two other wheels (see Fig. 2), and then to the weights. With the axis of the stator vertical (which it is to within 12′ of angle) these wires should be parallel and horizontal, conditions which are readily fulfilled.

The design, construction and testing of the wheels shown in Fig. 8 has required a great deal of attention. Ball, roller, and cone bearings were tested, and found to possess far too much friction to be suitable for these wheels, and so a knife edge was used. While this bearing is quite free from friction, and practical in use, it is necessary to locate the position of the knife edge relative to the centre of the wheel, a test which is not so easily made as might be expected.

Measurements.

The relation

$$J = \pi D n g (m_1 - m_2) / \{ (M_1 - M_2)(\theta_2 - \theta_1) \}$$

indicates what degree of accuracy is necessary in the various quantities in the right hand member, if J is to be correct to 1 in 10,000.

D, the diameter of the wheel, is 20 cm., and can be measured to the necessary accuracy. The revolutions, n, are counted. The acceleration of gravity, g, is accurately known for Melbourne. The masses, m_1 and m_2 gm., are readily found to the required precision.

With $\theta_2 - \theta_1 = 10°C.$ it is necessary to determine this difference to 1/1000°C, which is about the limit of accuracy obtainable with a platinum, or, in fact, any thermometer. The water flows past the platinum thermometers contained in Dewar flasks, as shown in Fig. 2.

The water, after passing through the calorimeter is collected in a copper can. A two-way tap turns it into this can at the beginning of the experiment, and at the same time starts the chronograph record; at the end of the experiment turning the tap causes the water to flow to a different vessel, and also stops the chronograph record. The water collected is weighed.

Distilled water contained in two thermally insulated tanks, so arranged as to give a constant head of about 240 cm. (8 feet) is used in the experiments.

The precision of the experiments will be limited (1) by the steadiness in the rate of generation of heat, and (2) by constancy of the loss of the heat, L, in the heavy and light experiments. The first of these has been satisfactory in the preliminary experiments, and if necessary, could be improved. The principal loss of heat, no doubt, occurs through the walls of the vacuum jacket of the calorimeter, and is proportional to the excess of the temperature of the inner wall (that is, the temperature of the inlet water θ_1) above the outer wall (that is, the air temperature θ_a). This difference $(\theta_1 - \theta_a)$ degree can be determined, it is expected, with sufficient accuracy to attain the desired precision.

Only preliminary determinations of J have so far been made, further experiments are now in progress.

We have to thank Mr. R. Berryman for the care he has taken and the success he has achieved in constructing the apparatus shown in the figures.

DESCRIPTION OF PLATES.

Plate X.

Fig. 2.—General view of apparatus.
,, 3.—Rotor with top removed, showing pole pieces and windings.
,, 4.—Rotor mounted.

Plate XI.

,, 5.—The two parts of the stator, on the left the iron cylinder in the channels for water, on the right the copper cylinder fitting over it.
Fig. 6.—Stator attached to torsion wheel with flask removed.
,, 7.—Stator with flask attached, showing plate with levelling screws resting on the top plate of Fig. 5.
,, 8.—Knife edge bearings.

[Note added 16th March, 1920:—Improvement in the brush contacts on the rotor has led to greater steadiness in the rotor field magnet current and therefore in the couple; this has made the water damping device mentioned in the text unnecessary.

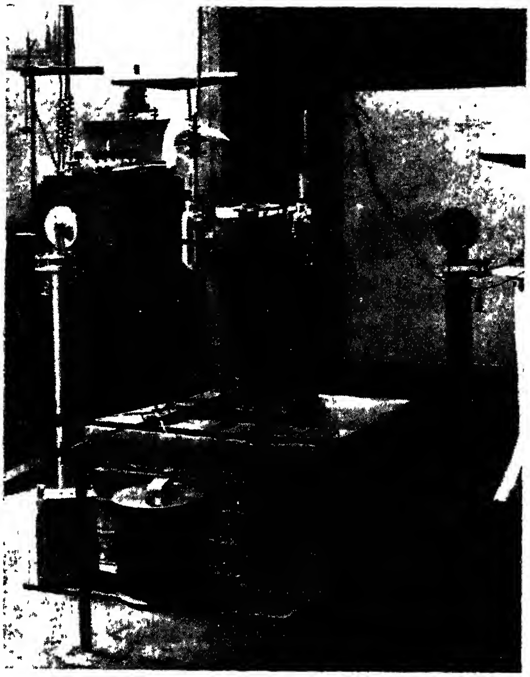


Fig. 2. General View of Apparatus.

Fig. 3. Rotor with top removed, showing pole pieces and windings.

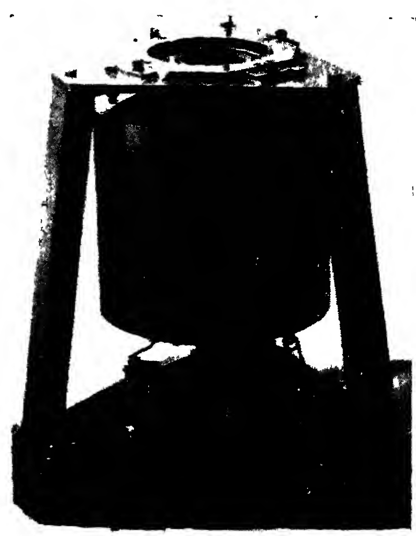


Fig. 4. Rotor mounted.

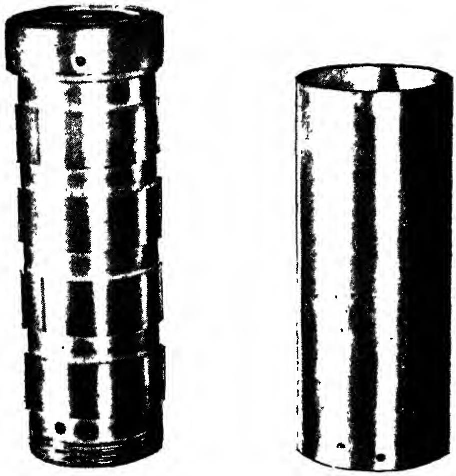


Fig. 5. The two parts of the stator, on the left the iron cylinder in the channels for water, on the right the copper cylinder fitting over it.

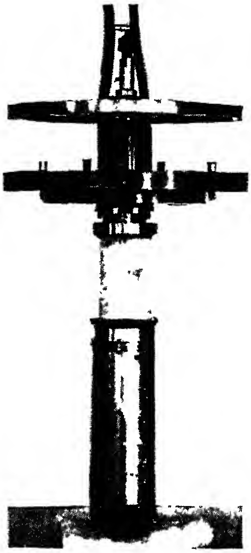


Fig. 6. Stator attached to torsion wheel with flask removed.

Fig. 7. Stator with flask attached, showing plate with levelling screws resting on the top plate of Fig. 5.

Fig. 8. Knife edge bearings.

It has also been shewn that the heat losses take place mainly from the tubes which lead the water into the flask and not from the flask itself. For a fixed rate of generating heat the loss of heat is proportional to the excess of the mean of the inlet and outlet water temperatures over the air temperature. The rate of loss of heat varies with the rate of generation of heat for fixed temperatures and has been shewn to be a linear function of it. This will enable the heat losses to be allowed for. J.K.R.]

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920].

ART. XI.—*The Design of an Induction Motor with large Air-Gap and Rotating Field Magnets.*

BY J. K. ROBERTS, B.Sc.

(Natural Philosophy Department, University of Melbourne).

(With 2 Text Figures.)

[Read 11th September, 1919.]

It will easily be seen that the apparatus described in another paper[1] in these Proceedings is an induction motor, with the following peculiarities:—

1. The field magnets are magnetised by direct current, and are rotated to produce the rotating magnetic field. This is necessary in order that the axis of rotation of the magnetic field may be accurately determined, and that there may be no movement of the magnetic field along the axis of rotation.

2. The armature consists of a hollow cylinder of solid copper with a soft iron core.

3. The machine works at 100% slip, i.e., the armature remains at rest.

4. The air gap is very much larger than usual to permit of the insertion of the Dewar flask.

The problem of designing the instrument was similar to that of designing an induction motor. A first approximation to the behaviour of the instrument may be made by supposing the copper armature replaced by another armature of the same size, consisting of very narrow strips of conducting material insulated from each other, the resistance of all the strips in parallel being equal to that of the copper cylinder from end to end, and each strip being connected at either end with that diametrically opposite to it by a perfect conductor.

If this armature be placed in a uniform magnetic field of strength H, which rotates at the rate of N revolutions per second, the usual theory of the induction motor gives the torque as:—

$$\psi = \pi N H^2 l^3 c^2 R n (R^2 + 4\pi^2 N^2 L^2)^{-1}$$

where l.cm. is the length of the armature, c.cm. is the diameter of armature. R. E.M. units is the resistance of each of the circuits (i.e., twice the resistance of one strip), n total number of

1. Laby and Roberts. A New Method of Determining the Mechanical Equivalent of Heat, page 148.

circuits (i.e., one-half the number of strips), and L.cm. the inductance of each of the circuits.

The quantity Hlc is the magnetic flux threading the armature, and is denoted by ϕ. Thus we have

$$\psi=\pi N n R\phi^2(R^2+4\pi^2N^2L^2)^{-1}$$

We may write $R=\rho n$ where ρ is a constant depending on the resistance of the original copper cylinder.

Thus

$$\psi=\pi N\rho\phi^2(\rho^2+\frac{L^2}{n^2}4\pi^2N^2)^{-1}$$

Let $L=\lambda n$ where λ is a constant

$$\psi=\pi N\rho\phi^2(\rho^2+4\pi^2N^2\lambda^2)^{-1}\ldots\ldots(1)$$

It should be noticed that writing $L/n=\lambda$ (a constant) takes into account the mutual action of the induced currents on one another. For suppose that we replace the original copper armature first by one consisting of n circuits and second by one consisting of $2n$ circuits where n is large. The currents flowing in adjacent circuits will be nearly the same both in magnitude and in phase, and since the circuits are near together the mutual inductance of two adjacent circuits will be practically equal to the self-inductance of either of them. Thus the flux threading a circuit when a certain current flows in it will, in the case of the armature of $2n$ circuits, be approximately twice what it is for the same current in the armature of n circuits. Writing $L=n\lambda$ we assume that it is exactly twice the value.

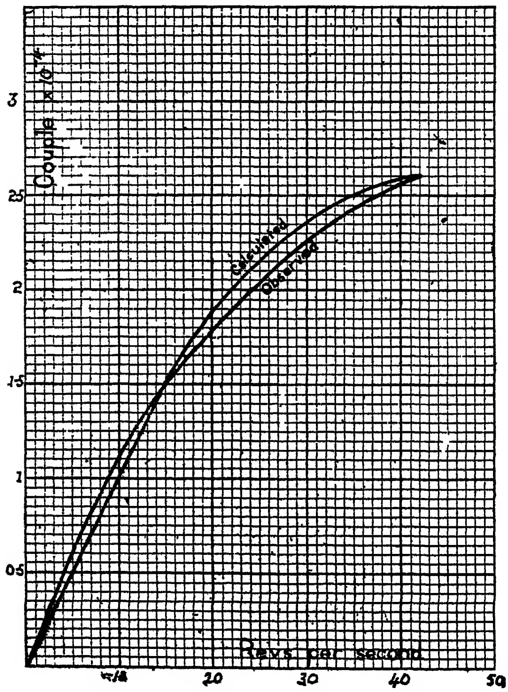
In order to determine ρ and λ for particular cases, the following experiments were carried out:—

Experiment (a).—A U-shaped permanent magnet was weighed and suspended by means of a bifilar suspension so that the poles hung downwards. An armature, consisting of a cylinder of copper with an iron core was placed midway between the poles and attached to a spindle, by means of which it could be rotated, a revolution counter was attached to the spindle. The couple acting when the spindle was rotated was measured by observing the deflection of a spot of light, which was reflected from a mirror attached to the magnet. The couple was measured for different rates of rotation of the armature. The value of ϕ was determined by winding the exploring coil of a Grassot fluxmeter around the armature and rotating it through 180°. This of course gives twice the value of $2.\phi$ The result obtained was $\phi=6.23\times10^3/2$ Maxwell. Mass of magnet, 2870 gm. Distance from mirror to scale, 54.5 cm. Length of suspending wires, 44.2 cm. Distance between suspending wires, 2 cm.

The couples obtained were the following —

Revolutions per second	Deflection of light on reversing direction of rotation of copper	Couple (absolute)
43 96	97 7 cm	$2\ 69 \times 10^4$
33 48	94 5 cm	$2\ 26 \times 10^4$
21 98	76 2 cm	$1\ 93 \times 10^4$
13 6	49 35 cm	$1\ 35 \times 10^4$

These results are plotted in Figure 1



Using the values at two points we may determine ρ and λ from equation (1) From the graph when

$N=42$, $\psi=2\ 6\times 10^4$, and when $N=15$, $\psi=1\ 5\times 10^4$,

We have therefore

$$\left.\begin{array}{l}\rho=2\ 772\times 10^4 \text{ E M U}\\ \lambda= 92\cdot 5 \text{ cm}\end{array}\right\} \quad (2)$$

Substituting these values in equation (1) we calculate the couples ψ for different values of N, with the following results —

$N=20$, $\psi=1\ 87\times 10$

$N=30$, $\psi=2\ 36\times 10^4$

These values are plotted in Figure 1, in the "calculated" curve.

Experiment (b).—Further experiments of the same nature were carried out by removing the armature from a series wound "Immisch" motor, and replacing it by a hollow copper cylinder with an iron core. The pole pieces were built up with cast iron so as to clear the copper by about one millimetre. The whole was mounted on a cradle dynamometer, and arranged so that the copper cylinder could be rotated at different speeds by means of a belt and pulleys of different sizes.

Current was passed through the field coils and the torque produced on rotating the copper measured in the usual way.

The value of ϕ was measured by making and breaking the current in the field coils, and noting the deflection of a fluxmeter with an exploring coil, wound around the copper. In each case the couple with zero flux was measured to eliminate the frictional couple. The following results were obtained :—

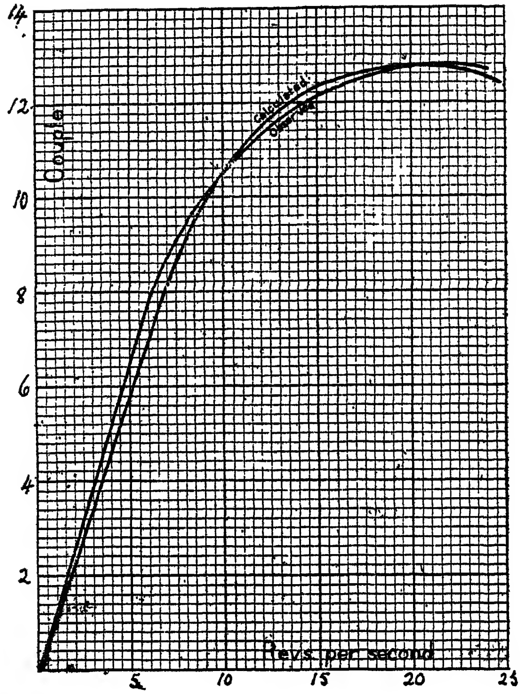
Revolution per second.	Value of 2ϕ	Mass of balancing rider.	Distance of rider from Centre.	Couple due to Eddy Currents.	Couple corrected to $\phi=2{\cdot}70\times10^5/2$
6.65	0	100	29 cm.	7.45×10^6	7.84×10^6
	2.72×10^6	200	52.5 cm.		
11.0	0	100	10 cm.	1.08×10^7	1.12×10^7
	2.74×10^5	200	60 cm.		
16.1	0	100	14 cm.	1.23×10^7	1.23×10^7
	2.79×10^5	200	70 cm.		
20.2	0	100	16 cm.	1.27×10^7	1.27×10^7
	2.79×10^5	200	73 cm.		
24.0	0	100	10 cm.	1.27×10^7	1.27×10^7
	2.79×10^5	200	70 cm.		

In order to correct the observed couples for variations in the value of ϕ it was assumed that the couple is proportioned to ϕ^2. To verify this, two experiments were carried out at the same rate of rotation with values of ϕ in the ratio of 1 to 2. The couples were measured as before. The values of the ratio Couple$:\phi^2$ were found to be

$$6.07\times10^3 \text{ and } 6.04\times10^3.$$

This justifies the assumption made.

The values of the couples corrected in this way are given in the last column of the table, and are plotted against revolutions per second in Fig. 2.



In order to compute the values of ρ and λ of Equation (1) for this case two points on the graph are used.

When $N=10$, $\psi=10.4\times10^6$, and when $N=20$, $\psi=12.7\times10^6$

In the same way as before we get

$$\left.\begin{array}{l}\rho=4.63\times10^4 \text{ E.M.U.}\\ \lambda=382 \text{ cm.}\end{array}\right\}\ldots\ldots (3)$$

Using these values of λ and ρ the couples which should correspond to different values of N can be calculated from formula (1) to be:—

$$N=15,\ \psi=12{\cdot}33\times10^6 \text{ and } N=25,\ \psi=12{\cdot}29\times10^6$$

These are plotted in Fig. 2 in the calculated curve.

In order to apply these results to the design of a new apparatus, it is necessary to compare the values of ρ as calculated above with the values of the resistances from end to end of the two cylinders which were used. If we do this we get the following:—

ρ/Resistance of copper cylinder =(a) 17·6 and (b) 24·2......(4)

The values of λ obtained were λ=(a) 92·5 and (b) 382......(5)

The reason for the fact that ρ is about twenty times the resistance of the copper from end to end, which we may call σ, is that if r is the resistance of each of the $2n$ strips by which the copper is replaced,

$$R=2n\sigma$$

The resistance R of each of the circuits formed by joining a pair of strips in series by two perfect conductors will be

$$R = 2r = 4n\sigma$$

$$\text{But } R = n\rho \text{ and } \therefore \rho = 4\sigma$$

That is, if the ends of the conducting strips were joined by perfect conductors, we would have ρ equal to four times the resistance of the copper from end to end. The remaining factor of five is due to the fact that the effective resistance of the paths joining the strips is not zero.

The large increase in the value of λ in the experiments with the Cradle dynamometer is probably due to the fact that in these experiments the air gap between the copper and the pole pieces was smaller than in the case of the permanent magnet.

Another point, which must be determined, before it is possible to design a new apparatus, is the extent to which the magnetic resistance of a magnetic circuit can be inferred from the dimensions of the apparatus.

To do this, the "Immisch" motor was used, and the flux threading the iron core was measured for different diameters of the core, and different magneto-motive forces, with the following results:—

Average area of air gap.	Length of air gap (both sides).	Magnetic resistance of air gap.	Magneto Motive force.	Magneto Motive force. Resultant Flux.
60.43	0.73	0.0121	3.47×10^3	0.0251
,,	,,	,,	6.01×10^3	0.0301
39.4	1.03	0.0261	3.70×10^3	0.0380
,,	,,	,,	6.61×10^3	0.0418
28.8	1.87	0.0650	3.71×10^3	0.0695
,,	,,	,,	6.84×10^3	0.0630

The numbers in the last column give the effective magnetic resistance of the Circuit.

Comparing these values with the values of the resistance as calculated from the dimensions, it will be noticed that for small air gaps, the effective resistance is larger than the calculated, and also that the value increases with increasing flux density. This means a higher magnetic leakage at higher flux densities. But when the air gap is 2.cm. long, the calculated and effective magnetic resistances are practically the same, and also the value of the effective resistance is almost independent of the flux density.

Certain dimensions in the new apparatus are fixed:—

(i.) The external diameter of the rotor is limited to 30 cm.

(ii.) The internal diameter of the pole pieces must be not less than 7.3 cm.

(iii.) The external diameter of the armature must not exceed 5.5 cm.

(iv.) The length of the armature must not exceed 13 cm.

(v.) Rough calculations shewed that the thickness of the copper should be 3 or 4 mm.

The copper was made 3.3 mm. thick, and 5.45 cm. in external diameter.

This makes the electrical resistance from end to end 4.46×10^3 E.M. unit.

From equation (4) we multiply this by 20 to obtain the value of

$$\rho = 20 \times 4.46 \times 10^3$$

Calculating the magnetic resistance from the dimensions we obtain the value

$$\text{Magnetic resistance} = 0.040.$$

Since the air gap is 1.9 cm. long it can be inferred from the experiments carried out that this will be the effective value of the magnetic resistance.

The flux obtainable is therefore given by

$$\phi = .4\pi(ni)/0.04 = 10\pi(ni)$$

where ni is the number of ampere turns.

It is proposed to run the apparatus at 1500 revolutions per minute, i.e., $N=25$.

$$\begin{aligned} \text{Power} &= 2\pi N\psi \\ &= 2\pi^2 N^2 \rho\phi^2(\rho^2 + 4\pi^2 N^2 \lambda^2)^{-1} \end{aligned}$$

Since $\frac{1}{2}$-Horse Power is required we have

$$3.73 \times 10^9 = 1{\cdot}086 \times 10^{12}(ni)^2(7.95 \times 10^9 + 2.47 \times 10^4\lambda^2)^{-1} \quad \text{......(6)}$$

If $\lambda = 92$ and 382 as in Equation (5) we obtain respectively

$$ni = 5.38 \times 10^3 \text{ and } 5.86 \times 10^3 \quad \text{........(7)}$$

The inductance term should not be greater than 356, as the air gap is nearly ten times as large as in the Experiment (b).

The heat generated in a winding of given size depends on the number of ampere turns.

It is, therefore, necessary to discover whether it is possible to dissipate the energy which would be generated in a winding of the size required by the dimensions of the apparatus. In making calculations it can be safely assumed that .05 watt can be dissipated per square cm. of the area of winding. With this assumption the possible number of ampere turns on each coil comes out to be 4500—that is, a total of 9000, which is more than is required. As only a limited voltage is available it is necessary to choose wire of such a gauge that the resistance will be low enough to allow the requisite number of ampere turns.

The poles were wound with 4720 turns of 24 gauge copper wire.

An experiment was carried out to determine the power of the apparatus so designed. It was found that when the apparatus was generating one half horse-power the current in the field winding was .575 amperes; since there are altogether 9440 turns this gives for magnetising current,

$$5.43 \times 10^3 \text{ ampere turns.}$$

This value lies between the predicted limits, viz.,

$$5.38 \times 10^3 \text{ and } 5.86 \times 10^3 \text{ as in equation (7).}$$

The rise of temperature of the winding was found from its resistance, the temperature coefficient of a sample of the wire having been measured. The temperature rose 47° with all the vents in the apparatus closed. Thus the apparatus realised the power for which it was designed. The ventilation caused by the vents was large, and with them open the rise was much smaller.

[Proc. Roy. Soc. Victoria, 32 (N.S.) Pt. 11., 1920].

Art. XII.—*Australian Phlebotomic Diptera:—New Culicidae Tabanidae and Synonymy.*

By. FRANK H. TAYLOR, F.E.S

Communicated by J. A. Kershaw.

[Read November 6th, 1919.]

The following paper contains descriptions of three new species of Diptera, which are contained in the genera *Uranotaenia*, *Silvius* and *Tabanus*.

Phibalomyia is substituted for the generic name *Elaphromyia*, as the latter is preoccupied, and two species of Tabanidae are sunk as synonyms.

Family CULICIDAE.

Uranotaenia albofasciata, sp.n.

Head clothed with bluish-white scales; antennae brown, plumes brown; palpi and proboscis brown.

Thorax brown, with blackish-brown, narrow scales. There is a broad band of white, small, flat scales on the lateral and anterior margins; prothoracic lobes white scaled; scutellum pale with black flat scales.

Abdomen covered with dusky scales, first segment white scaled, remaining segments, except the apical, with prominent white apical bands; venter apparently pale scaled.

Legs brown, femora pale beneath, last three tarsi of hind legs pale scaled.

Wings black scaled, base of wings white scaled, also apex of costa and the subcostal vein above the cross-veins, anterior basal cross-vein longer than and about twice its length from the anterior cross-vein, first fork-cell slightly narrower and shorter than the second fork-cell, base of latter nearer the base of the wing.

Length, 2.5 mm.

Habitat.—Northern Territory, near Darwin (G. F. Hill).

Abundantly distinct from other Australian species, and a well-defined member of the genus.

Type in Coll. Hill.

Family—TABANIDAE.

Sub-Family—PANGONINAE.

Phibalomyia, nom. nov.

Elaphromyia, Taylor, *nec* Bigot.

Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 749 (1917), op. cit., XLII., p. 517 (1917).

I am indebted to Prof. Dr. Bezzi for informing me that the name *Elaphromyia* has already been used by Bigot in 1859 (Dipt. Trypaneidae), thus invalidating its use in the Tabanidae. I therefore propose the above alteration.

Pseudotabanus queenslandi, Ricardo.

Corizoneura kurandae, Taylor.

Ann. Mag. Nat. Hist., (8), XVI., p. 273 (1915); Taylor, Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 748 (1917).

I am indebted to Mr. Kershaw, Curator, National Museum, Melbourne, for the courtesy of examining the Tabanidae contained in the Museum Collections, where there is a specimen of this species named by Miss Ricardo, thus establishing the identity of the two names.

Silvius distinctus, sp. nov.

Length, 10-13; length of wing, 9-11; width of head, 2.5-4 mm.

♀ *Head.*—Face and cheeks black, tomentum dirty grey, pubescence grey; beard grey; palpi black, slender; antennae black, base of third joint with a shallow angle, pubescence black on first two joints; front narrow, parallel, pubescence grey, black round the ocellar triangle, frontal callus as broad as the front; eyes black, bare.

Thorax chocolate-brown, pubescence black, prominent on sides; scutellum black with black pubescence; pleurae black with grey pubescence.

Abdomen, black, segmentations creamy, very broad on first segment, absent on penultimate and apical segments, segmentations narrowed in the median line, giving the abdomen the appearance of having a median black stripe; first two segments of venter with pale pubescence, penultimate and apical black, remainder with creamy segmentations.

Legs black, pubescence black.

Wings.—Basal half grey, rest clouded with black; veins black; stigma black; no appendix.

Habitat.—Northern Territory, Bathurst Island (G. F. Hill),

A very distinct and easily recognised species belonging to the *nigrapennis-fergusoni* group.

Type in Coll. Hill, paratype in Coll. Taylor.

Sub-Family TABANINAE.

Genus Tabanus.

Group VII. Abdomen, with one or more stripes, usually continuous.

Tabanus geraldi, sp. nov.

Length, 17; length of wing, 14; width of head, 5.75.

♀ *Head.*—Face and lower half of cheeks covered with grey tomentum, upper half of cheeks and subcallus, with dull golden tomentum; beard grey; front parallel with creamy tomentum and pubescence; vertex dusky; frontal callus small, pear-shaped, lineal extension reaching the middle of the front; first joint of antennae reddish-brown, pubescence grey, long, second joint black, very short, third joint black, base with a small, prominent tooth; palpi creamy-yellow, stout, ending in a blunt point, pubescence short, black mixed with pale at the base.

Thorax black, tomentum dirty grey, grey above wing roots, pubescence black and golden, grey above wing roots, black on sides; scutelum black, pubescence black, grey on posterior border; pleurae grey with grey pubescence.

Abdomen black, with dense black pubescence, with a median grey stripe terminating on the penultimate segment, lateral margin with dense, grey pubescence, sides of segments three to five yellowish; venter slate coloured with grey pubescence.

Legs black, basal third of fore tibiae reddish, mid and hind tibiae, except the apices, pale reddish-brown, pubescence grey on femora and tibiae, black on tarsi and apex of tibiae.

Wings clouded with yellowish on the veins except on the marginal cells; veins black, stigma reddish; no appendix.

Habitat.—Northern Territory, Bathurst Island (G. F. Hill).

A beautiful and very distinct species, quite unlike any other known Australian *Tabanus*.

Type unique in Coll. Hill, to whom it is dedicated.

Tabanus strangmanni, Ricardo.

Tabanus mastersi, Taylor,

Ann. Mag. Nat. Hist., (8), XIV., p. 393 (1914); Taylor, Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 754 (1917).

This appears to be a variable species, as both names refer to the same species.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920].

ART. XIII.—*On the Synthesis of Sugar from Formaldehyde and its Polymers, its Quantitative Relations and its Exothermic Character.*

BY ALFRED J. EWART, D.Sc., Ph.D.

(Professor of Botany and Plant Physiology in Melbourne University, and Government Botanist).

[Read 6th November, 1919].

In 1861 Butlerow found that on treating trioxymethylene trimolecular formaldehyde) with hot lime water, a sweet yellow, unfermentable syrup, "methylenitan," was obtained. Loeb[1] obtained an unfermentable "formose" syrup by the prolonged action of lime water on dilute formaldehyde, and by using magnesia obtained a "methose" syrup containing fermentable sugar. Fischer[2] showed that all three syrups were complex mixtures, containing a acrose and obtained this sugar, and β acrose from Barium hydrate and aerolein bromide. The a acrose is optically inactive fructose, and the β acrose is inactive sorbose.

The methods used for the preparation of sugar are mostly slow ones, involving incomplete reactions, and no attempts appear to have been made to determine any precise quantitative relations of the reacting materials.

In a previous paper[3] a method was described of rapidly polymerising formaldehyde to sugar by running dilute caustic soda into a boiling weak solution of formaldehyde, containing calcium formate. The advantages of this method are that there is a definite end reaction, so that quantitative estimations are possible, that the process is very rapid, requiring only a few minutes for completion, and that the amount of formaldehyde polymerised is very large. The residual products are calcium and sodium formates, and sugars, mainly pentoses and hexoses, any methyl alcohol formed boiling off.

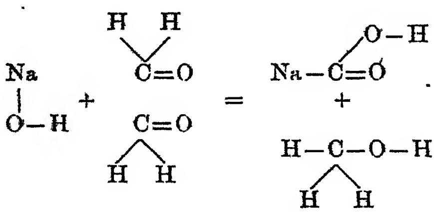
At low temperatures the reaction is extremely slow, and but little sugar is formed, while when strong caustic soda (35-40%) is

1. Loeb, Ber. D. Chem. Ges. 1887, Vol. 20, 142, 3039; 1888, Vol. 21, 270; 1889, Vol. 22, p. 470.
2. Fisher, Ber. d. Chem. Ges. 1894, seq.
3. Ewart, Proc. Roy. Soc. of Vict., 1919, Vol. XXXI., p. 379.

boiled with concentrated formaldehyde mainly sodium formate and methyl alcohol are produced.

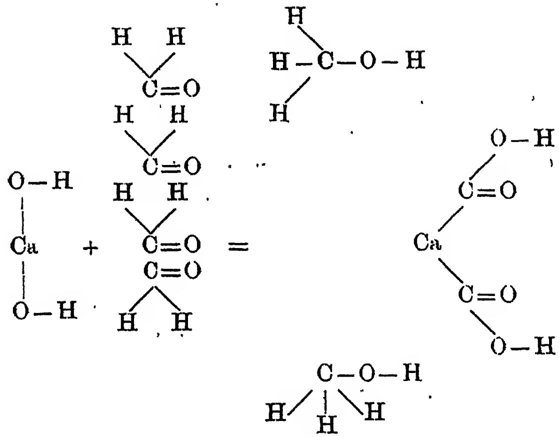
The purpose of the following investigation was to determine more closely the conditions determining the reaction, and bringing about the maximum polymerisation. The nature of the reaction appears to be as follows:—The sodium hydrate first reacts with the calcium formate, producing calcium hydrate, and sodium formate. The calcium hydrate has a more energetic polymerising action than sodium hydrate, and as this action takes place, it is converted into calcium formate, and methyl alcohol is produced. The amount of free alkali present at any given moment is, therefore, small in proportion to the amount of formaldehyde. If any free caustic alkali is present the sugar produced is caramelised on boiling, and the liquid turns brown. A drop or two of free alkali added in excess produces this change at the end of the reaction.

The polymerising action of an alkali appears to depend partly upon its valency. Thus the divalent Mg, Ca, Sr and Ba, hydrates appear to produce more polymerisation than the monovalent Na. and K, hydrates, the relative order being Ca, Sr, Ba, Mg, K, Na. Hence in the presence of a calcium salt, much more polymerisation takes place than if sodium hydrate is added directly to the boiling formaldehyde solution. We might picture the reaction with formaldehyde when no polymerisation takes place as follows:—



The sodium displaces hydrogen in the first CH_2O molecule, which together with the HO radicle of the sodium hydrate, displaces oxygen from the 2nd molecule. This is transferred to the first one, producing sodium formate and leaving methyl alcohol.

With calcium hydrate the reaction would take place similarly, but with four molecules of formaldehyde.



It is not easy at first to see why under any conditions this reaction should lead to a production of sugar, nor would it in all probability if it were a simple matter of a reaction between formaldehyde and an alkali. Bearing in mind the fact that when a previously measured quantity of dilute alkali is run into boiling dilute formaldehyde, the reaction is completed, and sugar is produced within two or three minutes, or even more rapidly if an excess of soda is used, whereas the same solutions kept at 12 to 15° C. for two months or more develop little or no sugar, it seems probable that this difference can hardly be due wholly to the influence of temperature on the rate of chemical reaction.

If a strong solution of formaldehyde is boiled down to $\frac{1}{7}$ or $\frac{1}{8}$ its bulk, and cooled, it solidifies to a white waxy mass of the polyhydrate of formaldehyde. None appears while the liquid is boiling, because of its low melting point. When a litre of 1 or of 2% formaldehyde is boiled nearly to dryness, and then cooled, it leaves a considerable solid residue of the polyhydrate of formaldehyde. Hence, in spite of the loss of formaldehyde vapour, a dilute solution can be concentrated by boiling. If the solution is evaporated at a lower temperature, or under reduced pressure all, or nearly all the formaldehyde escapes, and no residue is left. Presumably therefore, in boiling water, the substance exists mainly as the polydrate of formaldehyde, or as paraformaldehyde, which, on cooling, partially dissolves and partially dissociates to formaldehyde, so long as it has not separated out in mass. Hot water poured into paraformaldehyde or the solid polyhydrate soon acquires a smell of

CH_2O, and the solid slowly disappears in excess of hot water. In cold water a large part is still present, undissociated, after three days.

Paraformaldehyde, or the polyhydrate, dissolves in a few hours in excess of cold 2% NaHO, the liquid smelling of CH_2O, but also containing a little sugar. In cold, strong 35% NaHO, solid paraformaldehyde at once dissolves, forming a yellow liquid smelling of CH_2O, and containing sugar. It blackens and gives a caramel smell, with sulphuric acid, gives Molisch's test (α naphthol) for carbohydrates, and yields furfural on boiling with hydrochloric acid.

Hence, paraformaldehyde and the polyhydrate yield sugar immediately in contact with cold, concentrated soda, whereas formaldehyde does not.

If hot, 35% NaHO is added in slight excess to melted paraformaldehyde, there is a sudden evolution of methyl alcohol, and the resulting brown liquid contains sodium formate and reducing sugar.

Hence it may be concluded that in boiling water the formaldehyde exists mainly as paraformaldehyde or the polyhydrate, and that the alkali produces sugar, methyl alcohol and sodium formate, when it reacts with paraformaldehyde or the polyhydrate, but only or mainly sodium formate and methyl alcohol when it reacts directly with formaldehyde.

Suppose three molecules of di-molecular formaldehyde react with one of Barium or calcium hydrate, as follows :—

$$\begin{array}{l} C_2H_4O_2 \\ C_2H_4O_2 + Ba\begin{array}{l}HO\\HO\end{array} \\ C_2H_4O_2 \end{array} = \begin{array}{l} CH_3OH \\ Ba\begin{array}{l}COOH\\COOH\end{array} + \begin{array}{l}CHO\\CH_2HO\end{array} \\ CH_3OH \end{array}$$

The upper and lower molecules may be supposed to separate into CO and CH_3OH, the latter separating as methyl alcohol and the former combining with the BaH_2O_2 to form barium formate. In some manner not understood one of hydrogen is by a kind of enzymatic action transferred from one portion to the other of the central dimolecular formaldehyde

$$\begin{array}{l}CH_2O\\CH_2O\end{array} = \begin{array}{l}CHO\\CH_2HO\end{array}$$

yielding biose or glycollic aldehyde. This would represent a maximum percentage polymerisation to sugar of 33%, and if

tetroses or hexoses were formed directly from biose produced in this way, the percentage polymerization by weight would be the same. If, however, pentoses and hexoses were formed by the direct linking of formaldehyde to the glycollic aldehyde, without further production of formates and methyl alcohol, the polymerisation ratio for pentose would be 9 :5 (45%), and for glucose would be 10 :6 (60%). If a dissaccharide were produced, the maximum ratio would be 16 : 12, i.e., 75%.

A monovalent alkali such as sodium hydrate can react with single molecules of $C_2H_4O_2$, producing sodium formate and methyl alcohol, and will only produce a biose when 2 of sodium hydrate react with 2 of $C_2H_4O_2$, with a third molecule interpolated. The chance for this grouping is not more than half what it is in the case of a divalent alkali, where a single molecule reacts with not less than 2 molecules of $C_2H_4O_2$.

Methods.—The same result is not produced when the liquids are mixed cold, and then heated, as when the sodium hydrate is run into the boiling liquid. Thus 250 c.c. of water, with 5 c.c. of 10% calcium formate and 4 c.c. of 25.2% formaldehyde, after raising to the boiling point required, 7.2 c.c. of 3.5% NaHO to complete the reaction. If mixed cold with 7 c.c. of sodium hydrate, on raising to the boiling point a further addition of 0.4 c.c. of NaHO was required to complete the reaction. If mixed cold with 7 c.c. NaHO, and kept for 15 days at 15° C., on raising to the boiling point, the addition of a further 1.2 c.c. of NaHO is required to complete the reaction, and remove all CH_2O. Hence at low temperatures more formate is produced and less formaldehyde is polymerised to sugar, so that more soda is required to remove all the formaldehyde.

In carrying out estimations, a preliminary test was in each case carried out in an open beaker. The amount of sodium hydrate required was less than the full amount by the amount of CH_2O lost during the boiling. The same amounts of CH_2O, water and calcium formate, were then placed in a flask fitted with a condensing apparatus, so that the condensed steam washed back the escaping formaldehyde. The amount of sodium hydrate previously noted was then run in from a burette fitted to the cork, as rapidly as was possible without causing too violent ebullition.

The yellow tinge which indicates the completion of the reaction appears slowly with very dilute solutions, and the preliminary test must be checked by smell as well as colour. With strong solutions the yellow colour is produced before the reaction is completed, if

the soda is added more rapidly than the formic acid is produced. With a little practice these two sources of error are easily avoided.

A solution containing 250 c.c. of water, 5 c.c. of 10% calcium formate, and 5 c.c. of 31.5% of formaldehyde required 9.6 c.c. of 3.5% sodium hydrate, and required 25.8 c.c. of soda when no calcium formate was present. If no polymerisation had taken place, then the equation would be—

$$2\ CH_2O + 2NaHO = CH_3HO + Na\ CO\ OH$$

i.e., 60 grams of formaldehyde are required to neutralise 40 grams of sodium hydrate (or 38 grams of calcium hydrate).

3 grams of CH_2O are contained in $\frac{3 \times 100}{31.5}$ c.c. of 31.5% solution.

3 grams of NaHO are contained in $\frac{2 \times 100}{3.5}$ c.c. of 3.5 solution.

$$\therefore 1\text{c.c. of } 31.5\%CH_2O = 6\text{c.c. of } 3.5\%NaHO.$$

In the experiment 9.6 c.c. of soda were required, which represents 1.6 c.c. of CH_2O. Hence of the 5 c.c. of formaldehyde used 3.4 c.c. were theoretically polymerised to sugar. In this way, the apparent percentage polymerisation can be calculated under varying conditions, and with various concentrations, as thus:—

Water	c.c. of 10% $CaCO_2$	c.c. of 31.5% CH O	c.c. of 3.5% NaHO required	Per cent. of CH_2O polymerized
250 c.c.	5.0	5.0	9.6 c.c.	68
250 c.c.	0.0	5.0	27.8 c.c.	8

In addition to sugar, however, small amounts of by-products may appear. Thus perceptible amounts of dihydroxyacetone are produced when formaldehyde is polymerised to sugar by boiling with calcium carbonate.[4] Allowing for this possibility, the percentage polymerisation to sugar is between the theoretical maximum of 75% for the disaccharide and 60% for hexose.

The influence of the concentration of calcium formate present was found by varying the amount added, while keeping the water and formaldehyde constant. Five c.c. of 31.5% CH_2O were added to 250 c.c of calcium formate and water.

The soda first reacts with the calcium formate, forming calcium hydrate and sodium formate. The calcium hydrate reacts with the

4. H. and A. Culer, Ber d. D. Bot. Ges. 1905, 39, pp. 36, 39.

Water		c.c. of 10% $CaCO_2$		c.c. of 3.5% NaHO required		Per cent. of formaldehyde polymerized
250	-	0.0	-	27.7	-	8
250	-	0.1	-	23.9	-	20
250	-	0.2	-	19.8	-	34
249.5	-	0.5	-	17.5	-	42
249	-	1.0	-	14.1	-	54
248	-	2.0	-	11.6	-	62
247.5	-	2.5	-	11.2	-	62
246.5	-	3.5	-	10.1	-	66
245	-	5.0	-	9.8	-	68
240	-	10.0	-	9.8	-	68
235	-	15.0	-	9.8	-	68
230	-	20.0	-	9.7	-	68
210	-	40.0	-	9.7	-	68

formaldehyde, forming calcium formate and polymerising a portion to sugar. No sugar condensation is produced by boiling formaldehyde with either calcium or sodium formates.

From the equation $2\ NaHO + Ca(COOH)_2 = CaH_2O_2 + 2\ NaCOOH$ 80 grams of soda = 130 grams of calcium formate .. 10 c.c. of 3.5% NaHO = 5.7 c.c. of 10% calcium formate or 9.8 c.c.% of NaHO = 5.5 c.c. of 10% calcium formate. Hence maximum polymerisation is reached at a point where the soda and calcium formate are approximately equivalent. After that point an excess of calcium formate causes no increase in the percentage polymerisation. When still less calcium formate is present, the amount of soda required rises, more sodium formate being produced and less sugar.

An addition of 20 c.c. of 10% calcium formate causes an appreciable rise of the boiling point, and may be responsible for a slight loss of formaldehyde either as vapour or in the form of by-products other than sugar, and not involving any reaction with the calcium hydrate. Hence the slight decrease in the amount of soda required, which is in fact easily within the limits of error of the method used. In a further series of tests, the percentage of calcium formate was kept constant, and the amount of formaldehyde varied, 245 c.c. of water and 5 c.c. of 10% $CaCO_2$ were used in each experiment.

c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. of CH_2O polymerized
1	-	4.8	-	20
2	-	5.3	-	55
3	-	5.7	-	68
4	-	7.9	-	67.5
5	-	9.8	-	68
5.5	-	14.3	-	56
6	-	18.0	-	50
7	-	29.0	-	31

Apparently an excess of calcium formate interferes with polymerisation, when the formaldehyde is very dilute, while with the strong solutions since the 5 c.c. of 10% calcium formate requires 8.9 c.c. of 3.5% to convert it all into CaH_2O_2, portion of the 5.5, 6 and 7 c.c. of CH_2O has to be neutralised directly by the soda, and hence the percentage polymerization decreases.

Starting with 0.25 c.c. of 10% $CaCO_3$ and 0.5 c.c. of 31.5% CH_2O, and increasing or decreasing each proportionately, the following results were obtained :—

Water		c.c. of 10 per cent. $Ca(COOH)_2$		c.c. of 31.5 per cent. CH_2O		c.c of 3.5 per cent. NaHO required		Per cent polymerization of CH_2O
249.55 c.c.	-	0.62	-	1.25	-	5.1	-	32
248.75 c.c.	-	1.25	-	2.5	-	6.4	-	56
247.5 c.c.	-	2.5	-	5.0	-	13.0	-	58
245.5 c.c.	-	5.0	-	10.0	-	27.9	-	54
242.5	-	7.5	-	15.0	-	49.0	-	46

On the basis that 1 molecule of CaH_2O_2 reacts with 9 molecules of CH_2O, then 1 c.c. of 10% $Ca(COOH)_2$ represents 0.66 c.c. of 31.5 CH_2O.

Hence the amount of calcium formate present is below that theoretically required, and a large portion of the CH_2O reacts directly with the soda, giving a low percentage polymerisation. Further, two standards were taken, namely, (A) 5 c.c. of 10% $CaCO_2$ to 3 c.c. of 31.5% CH_2O, and (B) 5 c.c. of 10% $CaCO_2$ to c.c. of 31.5% CH_2O. The amounts of each were increased or decreased proportionately to one another in the two sets of tests, A and B, and added to 250 c.c. of water.

A

c.c. of 10 per cent. $Ca(COOH)_2$		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. polymerization of CH_2O
1.6	-	1.0	-	4.8	-	20
3.3	-	2.0	-	6.2	-	50
5.0	-	3.0	-	6 5	-	63
6.6	-	4.0	-	8.6	-	65
8.2	-	5.0	-	10.1	-	66
9.8	-	6.0	-	13.2	-	63
11.4	-	7 0	-	15.6	-	63
13.1	-	8.0	-	19.2	-	60

B

c.c. of 10 per cent. $Ca(COOH_2)$		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. polymerization of CH_2O
1.88	-	1.5	-	7.1	-	20
2.5	-	2.0	-	6.4	-	45
3.75	-	3.0	-	7.4	-	60
5.0	-	4.0	-	8.2	-	62
6.25	-	5.0	-	9.4	-	68
7.5	-	6.0	-	11.0	-	70
8.75	-	7.0	-	16.1	-	61
10.0	-	8.2	-	18.5	-	61

A, contains very nearly the theoretical amount of Ca formate required for the production of pentose sugar (1 mol. Ca formate = 9 molecules CH_2O). If any hexose or disaccharide is formed, less calcium formate would be required for optimal polymerisation. The higher polymerization in B indicates that some hexose or disaccharide is produced. With the intermediate concentrations, the results are very consistent, varying less than 1 % in duplicate tests. At the extremes, however, the results obtained particularly at the lower extreme are apt to vary somewhat, however, carefully the tests are performed.

Evidently, too great an excess of calcium formate interferes slightly with polymerisation at the higher concentrations, whereas in lower concentrations the opposite effect appears to be exercised. The maximum polymerisation is given with concentrations corresponding to 0.62% to 0.75% solutions of formaldehyde.

When strong solutions of alkali are used , or when the formaldehyde is concentrated, portion of the alkali is apt to attack the sugar produced, decreasing the apparent polymerisation.

When calcium formate is present, however, and the soda is added gradually, the percentage polymerisation decreases less rapidly with increasing concentration.

Thus, adding 10% c.c. of 31.5% CH_2O to 50 c.c. of 10% $CaCO_2$ (6.3% CH_2O), 28.8 c.c. of 3.5% Na HO was required to complete the reaction, and an abundance of sugar was formed. In this case 52% of the 6% CH_2O was polymerised. Using a mixture of 50 c.c. of 10% $CaCO_2$, and 20 c.c. of 31.5% CH_2O, and running in 35% NaHO, it is necessary to obtain an approximately accurate result to keep the temperature below boiling point, and to shake vigorously after each addition of soda until the precipitated lime dissolves as formate. Even then the liquid becomes distinctly brown before all the formaldehyde has been removed. The amount of soda averaged 6.6 c.c., and 1 c.c. of CH_2O equalling 0.6 c.c. of soda, the percentage polymerisation was 45.

Polymerisation by other divalent alkaline metals.

In the previous paper it was found that the presence of neutral barium, strontium or magnesium salts in boiling formaldehyde, to which caustic soda was added, increased the amount of polymerisation, and decreased the amount of soda required to neutralise the formaldehyde. Barium and strontium were not quite so effective as calcium, and magnesium had comparatively small effect. In these preliminary tests the importance of having a slight excess of

the neutral formate present was not realised, and hence further estimations were carried out in the same manner as for calcium.

It is, however, difficult to obtain exact quantitative determinations owing to the delay in the completion of the reaction after each addition of soda. If the latter is added too rapidly, so that any precipitate forms, this only dissolves very slowly, and any undissolved precipitate represents so much neutralised caustic soda. If, however, the boiling is very prolonged, the liquid turns yellow, while still containing formaldehyde, and when the reaction is completed the liquid appears to contain more by-products other than sugar. At least the liquid from a reaction completed in two hours boiling contained from 5 to 10% more reducing sugar, as determined by the Pavy method, than one completed by six hours' boiling, and the latter required slightly less caustic soda, although all other conditions and quantities were the same.

For these tests it was found best to use a simple type of condensing flask, with the burette passing through the cork, and with an open upright tube 4 ft. long as the condensing column. Of the 500 c.c. of water used 100 c.c. was allowed to trickle slowly down this tube during the two-hour period over which the boiling, and addition of soda, were spread when strontium and barium salts were used. As the soda burette becomes slightly warmed during the boiling, its final reading must be checked after it has cooled to the original temperature.

Strontium.—Crystallised strontium formate was used as a 10% solution. The proportions used were 20 c.c. of strontium formate, 500 c.c. water, and 70 c.c. of 31.5 formaldehyde. The amounts of 3.5% sodium hydrate required varied from 20.8 c.c. to 21.2, representing an apparent polymerisation of formaldehyde of 65%.

Barium.—In the presence of barium formate, using similar quantities, the reaction was slighly more rapid. The amounts of soda required to neutralise all the formaldehyde varied from 20.4 to 20.9, representing a percentage polymerisation of formaldehyde of 65 to 66%.

Magnesium.—Owing to the highly insoluble character of the hydrate, its polymerising action is extremely slow, and quantitative estimations are difficult to obtain. A preliminary estimation was made, using an excess of the hydrate precipitated in the liquid by caustic soda. In this case the only advantage of using caustic soda is that the hydrate is precipitated in a more bulky and flocculent form than if the dry hydrate is used. From the amount

of magnesium hydrate, remaining after all the fomaldehyde had been polymerised, the approximate amount required was estimated.

Using these proportions more exact estimations were made. The condensing flask was provided with a condensing tube 4 ft. long, which was sealed at the upper end as soon as the liquid had been brought to boiling point, and allowed to blow out to a thin safety bulb. The liquid was then kept just at the boiling point for several days. The liquid became brown before the end of each experiment.

In the presence of magnesium formate, 500 c.c. of water and 10 c.c. of 31.5% formaldehyde, after the addition of 23 c.c. of 3.5% sodium hydrate, a small amount of a white insoluble solid still remained after several days. This was not Mg H_2O_2, and was insoluble in dilute acid, the liquid was faintly acid, and still contained a small amount of CH_2O.

Using 750 c.c. of water, 15 c.c. of 31.5% CH_2O, a slight excess of magnesium formate and 40 c.c. of 3.5% NaHO, all the formaldehyde was removed, after boiling for 22 hours, the liquid was faintly acid, and contained a small amount of white solid, inconspicuous when suspended, but not consisting of Mg H_2O_2. This represents a percentage polymerisation of 58. A further test gave a polymerisation value of 57. As a small amount of the magnesium hydrate appears to form an insoluble compound, and as during prolonged boiling a trace of the formaldehyde is oxidised directly to formic acid, which represents a further direct removal of magnesium hydrate without producing any polymerisation, the polymerisation value of 57 to 58 for the divalent Mg corresponds fairly well with that of 65-68 for the divalent Ca. Ba. Sr, and contrasts sharply with the values for the monovalent K and Na of 8 to 14%.

Potassium.—On the basis of the conclusions given above, that the relative efficiency of calcium and sodium as polymerising agents depends upon the former being divalent, and the later monovalent, we should expect to find equivalent solutions of the monovalent metals, sodium and potassium, exercising a very much inferior polymerising action, and that in the presence of calcium formate it should be a matter of indifference whether sodium hydrate or an equi-molecular solution of potassium hydrate was used to bring about polymerisation.

As a matter of fact the correspondence is even more exact than

might have been expected. Thus, using 250 c.c. of water to the proportions given the following were the results :—

c c. of 10 per cent. calcium formate		c.c. of 31.5 per cent. CH_2O		c.c. of 3 5 per eent. NaHO required		Per cent. polymerization
10.0	-	5	-	9.8	-	68
0.0	-	5	-	27.7	-	8
0.0	-	4	-	22.6	-	6
				c.c. of 4.9 per cent. KHO required		
10.0	-	5	-	9.6	-	68
0.0	-	5	-	26.1	-	14
0.0	-	4	-	20.9	-	12

Non-reducing sugar.

In order to determine whether any non-reducing sugar was formed, to 50 c.c. of calcium sugar concentrated to a thick syrup, BaH_2O_2 solution was added. A small amount of white precipitate was formed. This was filtered, washed, and treated with CO_2. The filtrate contained a non-reducing sugar, giving reduction after boiling with a drop of H_2SO_4, and pink with resorcin and HCl., but no reaction with phenylhydrazin. Hence a small amount of disaccharide resembling cane sugar is formed, but the percentage is much less than 1%, and is greater if the boiling is prolonged during the production of sugar.

In sugar synthesis by Ba and Sr, a small amount of ppt. always forms, which does not dissolve even if boiled with excess of CH_2O. It yields sugar after treatment with CO_2, and is apparently a compound of a disaccharide with BaH_2O_2, or Sr H_2O_2. The amount is always small if the sugar condensation is carried out under proper conditions.

Fischer has shown that in the presence of acids condensation of disaccharides from mono-saccharides, particularly from levulose, is possible, and it seems probable that any disaccharides formed are not produced by directly polymerisation from CH_2O, but indirectly from the monosaccharides. Hence their appearance would not necessarily increase the apparent polymerising action of the alkali.

Reducing power of sugar syrup.

Although the synthetic syrup contains a mixture of sugars, it is of some interest to determine its reducing power in glucose equivalents.

The syrups were formed by running 4.9% potassium hydrate into boiling formaldehyde, containing calcium formate.

	Water		10 per cent. Ca formate		31.5 per cent. CH_2O		Amount req. of 4.9 per cent. KHO
A—	750	-	15 c.c.	-	15 c.c.	-	27.6 c.c.
B—	750	-	25 c.c.	-	15 c.c.	-	29.5 c.c.

10 c.c. of A were diluted to 50 c.c. with 10% NH_4HO, and titrated against 50 c.c. of Pavy's solution (8.316 grams copper sulphate per litre).

34.7 c.c. neutralised 50 c.c. of Pavy. There was no increase in the reducing power after boiling with citric acid.

After heating with 1 drop of HCl., 34.5 c.c. reduced 50 c.c. of Pavy

After heating with 5 drops of HCl., 35.4 c.c. = 50 of Pavy.

After heating with 10 drops, 44.5 c.c. decolorised 50 c.c. of Pavy.

Hence a trace of non-reducing sugar may be present capable of inversion by HCl, but excess of HCl causes the decomposition of some of the sugar.

Repeating A and B several times, the maximal reducing action obtained was 33.5 c.c. = 50 c.c. Pavy = 0.025 gram glucose, and, therefore, the total bulk of 805 c.c. of syrup had a total reducing power equivalent to 1.348 gram of glucose. Since 15 c.c. of 51.5% CH_2O were used; in terms of glucose this would represent a sugar polymerisation of 29%.

In a test with caustic soda alone, 35% caustic soda was run into boiling 31.5% CH_2O. A yellow tinge appeared at once, but to neutralise all the formaldehyde 25 c.c. of 31.5% CH_2O required 14.8 c.c. of 35% NaHO. As 14.8 c.c. are equivalent to 23 c.c. of CH_2O, this represents a theoretical polymerisation of 8%. The liquid contained reducing sugar equivalent to 0.13 gram of glucose, which represents a polymerisation in terms of glucose of 2%. Owing to the strength of the alkali used, however, much of the sugar formed is caramelised.

The action of alkalies on the polymers of formaldehyde.

The concentrated aqueous solution of CH_2O is supposed not only to contain volatile CH_2O, but also hydrates such as $CH_2\begin{matrix}-O-H\\-O-H\end{matrix}$, and $(CH_2)_2O(OH)_2$. The latter is a non-volatile polyhydrate which leaves a waxy solid on complete evaporation, supposed to be diformaldehyde, "paraformaldehyde" $(CH_2O)_2$. The better known triformaldehyde or metaformaldehyde $(CH_2O)_3$ is stated to be distinguished from diformaldehyde by its subliming just over 100°C., whereas its M.P. is 171-172°C., and by its insolubility in water, alcohol and ether.

In contact with peroxides of Ba or Sr, and water, polymerised formaldehydes are catalytically changed into the simple form, and much heat evolved.

There appears to be some uncertainty as to the real nature of "paraformaldehyde," and as to how best to obtain it in pure form.

If a saturated solution of formaldehyde is evaporated by rapid boiling to $\frac{1}{5}$ its bulk, or a 30% to $\frac{1}{6}$ its bulk, and then allowed to cool, it sets as a white waxy solid. A solution containing 175 90°C., then giving off water and CH_2O, recondensing as a solution grams of CH_2O yielded 122 grams of this solid. It melts at of CH_2O, or escaping as gases. In a desiccator or in air it slowly loses water and CH_2O; after three weeks in a desiccator, losing 36% of its weight. If heated to just over 100° c.c. it boils, and after all the water has been driven off the residue sets to a harder waxy solid, with a specific gravity slightly greater than the hydrate (1.2). This gives off CH_2O vapour when heated.

Apparently the first solid obtained is the polyhydrate. This is, however, unstable. After two to three weeks in a dessicator, frequently exhausted by a Geryck pump, a considerable loss of water and CH_2O takes place (nearly 40%), and the residue sublimes on heating. The solid lost on the average 0.8% of its weight daily, until 38% has been lost, by which time the daily loss had fallen to 0.2%.

Both the polyhydrate and the "paraformaldehyde," when in mass, remain incompletely dissolved in cold ether, alcohol or water, even after three days, but in hot water or alcohol dissolve rapidly. On cooling the alcoholic solution, a larger proportion of white solid separates out, which blackens and gives a smell of ether, with warm strong H_2SO_4, and decomposes on heating. It is apparently a compound of CH_2O, with alcohol.

In the intermediate condition between hydrate and $C_3H^6O_3$. changes to CH_2O when heated in water to 130°C. Samples of $C_3H_6O_3$ prepared in various ways, were all found to dissolve slowly, after prolonged heating in excess of boiling water, when in the form of a fine powder. Large pieces, however, give for a considerable time the appearance of being insoluble.

In the intermediate condition between hydrate and $C_3H_6O_3$. it dissolves more readily in hot water than $C_3H_6O_3$, melts partially before subliming, and sublimes into oily drops, which set to a white wax on cooling. When conversion is complete the $C_3H_6O_3$ sublimes without melting, and deposits as a white solid.

The production of sugar from solids.

If dry $(CH_2O)_3$ is mixed with crystalline Barium hydrate (Ba H_2O_2 8 H_2O) and ground intimately in a mortar, a pasty mass is obtained, smelling of CH_2O. If this is gently warmed at one point a sudden and violent exothermic reaction spreads through the mass, CH_2O, water vapour and methyl alcohol are given off, and the temperature rises to 100°C. or 110°C. if a large mass is used, with an excess of barium hydrate. The resulting brown, gummy residue contains no formaldehyde, but reducing sugar appears.

Similar reactions are given with strontium hydrate, but with dry calcium hydrate the reaction is imperfect. "Paraformaldehyde" and the solid polyhydrate may be used instead of metaformaldehyde. In the latter case the temperature does not rise beyond 100°C., owing to the large escape of steam.

Metaformaldehyde and alkali.

The solid was ground with dry barium hydrate in varying molecular proportions, and the pasty mass weighed out to contain in each case 0.45 gram $(CH_2O)_3$, After warming, the residue was dissolved in warm water, the Barium formate and any excess of Barium hydrate precipitated as sulphate, and the filtrate tested by the Pavy method. Any $(CH_2O)_3$ remaining is filtered off with the Barium sulphate, and if any CH_2O is present, the ammonia used the Pavy method. (Any $(CH_2O)_3$ remaining filtered off with the affect the tests for reducing sugar. Similarly the formic acid is converted into ammonium formate. As a matter of fact the reaction is a very complete one, and with the proper proportion of barium hydrate every trace of formaldehyde is removed.

The following proportions were used :—

A and B.	1	Barium hydrate	(0.85 gram)	to 1.8 $(CH_2O)_3$	(0.45 gram)
C	1	,, ,,	(0.42 ,,)	to 3.6 $(CH_2O)_3$	(0.45 gram)
D and E.	1	,, ,,	(0.28 ,,)	to 5.4 $(CH_2O)_3$	(0.45 gram)

with the following results—

Proportion	Final reaction	Loss of weight after warming	Mass	Reducing equivalent in glucose
A. 1 : 1.8	Strongly alk.	0.21	Brown	0.075 gram
B. 1 : 1.8	,, ,,	0.23	,,	0.074 ,,
C. 1 : 3.6	Less ,, ,,	0.23	Yellow	0.073 ,,
D. 1 : 5.4	Weakly alk.	0.17	White or	0.061 ,,
E. 1 : 5.4	,, ,,	0.14	pale yellow	0.066 ,,

In B and E the separated ground solids were mixed lightly but thoroughly, and then warmed. In E the mass was mixed and ground with a glass pestle, while the reaction was taking place.

Further investigation showed, however, that to obtain maximum polymerisation, with a minimum loss, quantities totalling not less than 2 grams must be used. Otherwise the reaction is not so complete, and hence the low production of sugar above. The results of three tests are given, the second with a sample of $(CH_2O)_3$ obtained from the Chemistry School, the first and third with samples prepared from a bulk sample supplied by Cuming, Smith's, and purified by sublimation. The proportions used were approximately 4 of $(CH_2O)_3$ to 1 Ba H_2O_2. In all three cases the residue was brown, contained no formaldehyde, and was weakly alkaline.

CH_2O_3		BaH_2O_2		Loss of weight		Reduction equivalent of residue in terms of glucose
1.25 gram	-	0.78 gram	-	0.38 gram	-	0.37 gram
1.25 ,,	-	0.78 ,,	-	0.33 ,,	-	0.39 ,,
2.5 ,,	-	1.56 ,,	-	0.78 ,,	-	0.72 ,,

This represents a polymerisation equivalent in terms of glucose of 30 to 32%. The maximum polymerisation in terms of glucose obtained when using boiling dilute formaldehyde was 29 to 30%. That is, in spite of the loss of formaldehyde vapour, more sugar is obtained from solid metaformaldehyde and crystalline barium hydrate than when the reaction is carried out with dilute solutions in water.

The last experiment (with 2.5 grams) was carried out in a small distilling flask. The distillate weighed 0.45 gram, so that apparently at least $\frac{1}{8}$ of the formaldehyde is lost as vapour. This would increase the actual polymerisation value in terms of glucose to 36%.

Even if an excess of Barium hydrate is used, so that no trace of formaldehyde remains in the residue, the filtered extract gives distinct aldehyde reactions, and hence presumably contains the biose sugar, glycollic aldehyde.

Paraformaldehyde and the polyhydrate.

The former was prepared by melting the latter and heating till water vapour ceased to escape. Similar results were obtained, but the production of sugar was less, and the hydrate gave off more water vapour during the strongly exothermic reaction.

$(CH_2O)_2H_2O$	Alkali		Loss of weight	Glucose equivalent of reducing sugar	Per cent. polymerization in terms of glucose
2.09 gram	SrH_2O_2	0.8 gram	0.63 gram	0.35	17%
1.53 „	BaH_2O_2 = 1	„	0.55 „	0.34	22%
1.69 „	NaHO	0.5 „	0.74 „	0.08	5%
$(CH_2O)_2$					
1.25 „	BaH_2O_2	1 „	0.41 „	0.33	26%

In each case the amount of alkali was sufficient to remove all the formaldehyde. When sodium hydrate and the polyhydrate are pounded together, the reaction starts spontaneously, and is very violent. There is a heavy loss of formaldehyde vapour, and much of the sugar is caramelised. For this reason the percentage polymerisation is less than when a boiling dilute solution of formaldehyde is neutralised with dilute sodium hydrate.

If the reaction is started by locally warming several grams of the mixture in a small distilling flask, a large amount of distillate is obtained without applying further heat. This consists in the case of the polyhydrate (and crystalline BaH_2O_2) of water, methyl alcohol and formaldehyde.

If a slight excess of the polydrate is used, the whole of the BaH_2O_2 is converted into barium formate. This can be obtained by dissolving the residue in a little water, and adding an equal bulk of alcohol. A large part of the sugar slowly settles out with some barium formate. On filtering after 48 hours standing, and doubling the bulk in the alcohol, a second ppt., mainly of barium formate, is produced, which can easily be washed and purified.

A point worth noting is that if the finely ground polyhydrate is mixed thoroughly with finely ground crystalline barium hydrate, the mixture smells strongly of formaldehyde, and its temperature falls 15°C. for some time. The temperature then slowly rises, but not appreciably above that of the room. The mixture slowly develops traces of reducing sugar, but does not undergo any complete reaction even after days in contact, until this is started by heating one point of the mixture.

A similar preliminary fall of temperature is shown with di- and tri-molecular formaldehyde. If, however, these are mixed with freshly slaked dry quicklime, or with powdered calcined barium or strontium hydrates, the mixture remains dry, the fall of temperature is hardly noticeable, and on heating the mixture locally the reaction does not spread. Only the parts heated turn brown, and methyl alcohol distils over (yielding methyl iodide with Iodine and red phosphorus). The residue contains an abundance

of reducing sugar, but the reaction is imperfect, and is difficult to complete without overheating portion of the mixture, or volatilising much of the formaldehyde.

It is the presence of water of crystallisation in the crystalline barium hydrate which enables its reaction with solid polymers of formaldehyde to progress, and be completed throughout the whole mixture. Some of this water of crystallisation is liberated by mere contact with solid formaldehyde.

Summary of Results.

Cold dilute solutions of formaldehyde yield with alkalies, formates and methyl alcohol, sugar polymerisation being inappreciable. The reaction is incomplete after months in contact.

Maximum sugar production is given with boiling liquids, and the reaction is completed almost instantaneously.

The maximum sugar polymerisation varies from 68% (Ca), 66% Ba, 65% Sr. to 58% Mg. for divalent alkalies, and from 14% (K) to 8% (Na) for monovalent alkalies. The high polymerisation value (68%) estimated from the amount of alkali required for neutralisation indicates either that the pentoses and hexoses are produced directly, or that glycollic aldehyde is produced by the reaction yielding formates, and 3 or 4 of formaldehyde added to it without further decomposition of formaldehyde. This is also indicated by the appearance of pentoses. Polymerisation of biose would yield tetroses or hexoses, but not pentoses.

The greatly increased polymerisation when soda is run into a solution of formaldehyde containing calcium formate is merely due to the fact that calcium hydrate becomes the polymerising agent, and as a divalent metal exercises a greater polymerising action. There is no evidence of any katalytic action, as was formerly supposed.

In terms of glucose, the reducing sugars produced represented a polymerisation of 29% for calcium, and 2% for sodium. Apparently the sugars have half the reducing power of glucose.

The solid polymers of formaldehyde yield sugar readily, and abundantly, when in contact with solid alkalies. The most complete reaction is shown with the powdered crystalline hydrates of Ba and Sr. A feeble endothermic reaction precedes the violent exothermic one. The production of sugar is greater than with solutions, the polymerisation equivalent in terms of glucose being 30-32%.

In all cases the sugar is a by-product in a reaction, yielding for-

mates and methyl alcohol. The alkali is used up and the amount of sugar formed is proportionate to the amount of alkali consumed. The reaction is, therefore, widely different from an enzymatic one. No mode of enzymatically polymerising formaldehyde to sugar is known, such as might occur in plants.

Conclusions.

The foregoing research was undertaken in order to elucidate certain points of interest to the plant physiologist concerning the possible modes in which plants could synthesize sugar from formaldehyde, which the purely chemical researches available did not appear to answer. It has led me to the conclusion that a production of formaldehyde does not form a stage in the synthesis of sugar by plants, and that it would be a very wasteful, indirect way of producing sugar.

The reasons on which this conclusion are based are as follow:—

(1) In 1908 I showed that when chlorophyll was oxidised in the presence of light, and in the absence of carbon-dioxide, one of its decomposition products was formaldehyde, and that this was the explanation of the appearance of traces of formaldehyde in green leaves exposed to light. This result has been confirmed by Schryver and by Jorgensen and Kidd.* Schryver stated that more formaldehyde was produced when carbon dioxide was present, but as the results of experiments extending now over ten years, there can be no doubt that the process is purely one of photo-chemical oxidation, and is not increased by the presence of CO_2.

(2) There are strong reasons for concluding that alkalies do not polymerise formaldehyde to sugar, or only to a very slight extent, but instead produce methyl alcohol and formates. Pronounced sugar formation only takes place when the alkali acts on a polymer, such as paraformaldehyde, the polyhydrate, or metaformaldehyde. The production of sugar from a solution of formaldehyde mainly depends on the presence of the polyhydrate in the solution. With cold dilute solutions the production of sugar is almost negligible. For a complete reaction and high polymerisation a temperature of 90°C. to 100°C. is necessary. Even then the polymerisation is only partial, and formates and methyl alcohol are formed in large amount. These are not known to accompany photosynthesis in plants.

* Ewart, Proc. Royal Soc. Lond., B 1908, Vol. 80, p. 30; Schryver, *ibid.* 1910, 82, p. 226; Jörgensen and Kidd, *ibid.* 1917, 89, p. 342.

(3) Every method of polymerising formaldehyde to sugar yields a mixture of sugars, in which pentoses are included, and often form the main yield. Pentoses are not direct products of photosynthesis in plants, but instead hexoses and their 6 or 12 carbon derivatives, starch and polysaccharides.

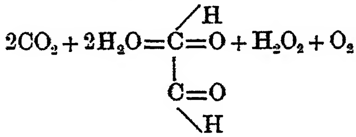
(4) It is as easy for the plant to produce sugar directly as to produce formaldehyde. Thus taking the process in three stages—

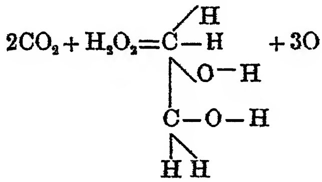
$$\left\{\begin{array}{l} CO_2 + H_2O = CHO + HO + O \\ CO_2 + HO + H_2O = CH_2HO + 3O \\ CHO + CH_2HO = \begin{array}{c}CHO\\CH_2HO\end{array}. \end{array}\right. \quad \text{Biose sugar.}$$

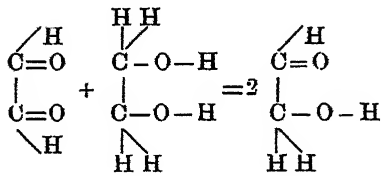
or in one stage:—

$$2CO_2 + 2H_2O = \begin{array}{c}CHO\\CH_2HO\end{array} + 2O_2$$

The equation could also be represented as in 1, 2, 3.

(1) 

(2) 

(3)  Biose.

(5) This Biose sugar (glycollic aldehyde) is readily polymerised by sodium carbonate to acrose, a hexose sugar.

(6) This mode of producing sugar would be endothermic, as in the plant. The production of sugar from the polymers of formaldehyde involves an exothermic reaction which, under appropriate conditions, is very violent.

(7) Magnesium hydrate has a slower polymerising action on formaldehyde than any other metallic alkali. Since the presence of magnesium in chlorophyll is hardly accidental, its relations to glycollic aldehyde when it is in organic combination merit future

investigation. For it to be able to act as a polymeriser in the plant, it must act in ferment fashion without itself being altered or brought permanently into different combination. That is the polymerising action must differ widely from that of alkalies on formaldehyde and its polymers.

(8) If photosynthesis involves an actual combination of chlorophyll and carbon dioxide, which combination is distintegrated by light into chlorophyll and carbohydrate, hexoses would be formed as readily directly as through the intervention of biose and the chlorophyll would act as a lytase or carboxidase enzyme.* Its mode of action in producing glycollic aldehyde would also be that of an enzyme.

* Proc. Royal Soc. of Vict. 1918, Vol. xxx. p. 208.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XIV.—*Contributions to the Flora of Australia, No. 28.*

BY

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AND

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(With Plate XII.)

[Read October 9th, 1919.]

Acacia dawsoni, R. T. Baker. (Leguminosae).

Mitta Mitta, Mr. Clinton, Nov., 1918.

New for Victoria,

Acacia leprosa, Sieb. "Leper Acacia." (Leguminosae).

Between Eaglehawk and Sydney Flat, Victoria, David J. Paton,. August 23rd, 1919. An unrecorded locality in Victoria for this plant.

Adriana, Gaud. (Euphorbiaceae).

Pax in Engler's Pflanzenreich, IV., 147-II., pp. 17 to 21 (1910) practically agrees with Bentham's arrangement of the genus *Adriana*. Maiden, in his Census of New South Wales Plants, follows them.

Distribution of Adriana.

A. glabrata, Gaud. V., N.S.W., Q., N.A.

A. glabrata, var. acerifolia, Pax. (A. acerifolia, Hook). V., N.S.W., Q.

A. glabrata, var. Cunninghamii, Mül. Arg. V.

A. glabrata, heterophylla, Müll. Arg. V.

A. tomentosa, Gaud. W.A., N.A.

A. Hookeri, Müll. Arg. (incl. 2 varieties). V.

A. quadripartita, (Lab.) Gaud. W.A., T., V.

A. Klotzschii, (F. v. M.) Müll. Arg. S.A., V.

In Mueller's Second Census, the foregoing species are reduced to two, but as they are all readily distinguished from one another they must be kept separate.

AGROSTIS LACHNANTHA, Nees. (Gramineae).

Dookie, Victoria, W. D. Wilson, February, 1911. Canterbury and Mitcham, Victoria, R. Ardagh, December, 1918.

This useful pasture grass, a native of South Africa, is now apparently establishing itself as a naturalised alien in Victoria.

AIZOON ZYGOPHYLLOIDES, F. v. M. (Aizoaceae).

This species was recorded in the Victorian Naturalist, Vol. XVII., p. 203 (1901), as being new for Victoria. This was evidently an error, as the specimens from Corio Bay, Geelong, Jan., 1901, on which the record was founded, proved on examination to be Mesembryanthemum angulatum, Thunb., a native of South Africa, which has been recorded as an introduction at Coode Island, in Victoria. (Collected by J. R. Tovey, 1908.) Aizoon zygophylloides is only found in West and South Australia, New South Wales and Queensland.

ALHAGI CAMELORUM, Fisch. "Camel Thorn" (Leguminosae).

Tongala Irrigation District, Victoria. E. Kendall, 13/1/1920.

This plant, a native of Central Asia and the Orient, was previously recorded as growing wild in Victoria from the North-eastern district. It is now evidently spreading westward.

AMARANTHUS DEFLEXUS, L. (Amarantaceae).

Elwood, Victoria, E. J. Semmens, November, 1917.

Another locality in Victoria for this weed. It is a native of Europe, and is now apparently in the process of naturalisation in this State.

ARUNDO PHRAGMITES, L. (Phragmites communis., Trin.) "Common Reed." (Gramineae).

Daly River, Northern Territory, May, 1919.

Probably fairly common in the Northern Territory, but only previously recorded from Port Darwin, M. Holtze, 1889. It may possibly in some cases be included under the name Arundo Roxburghii, F. v. M. The plant is used for thatching hay ricks and sheds in Victoria. It has a certain fodder value when young, and may have other economic uses.

BASSIA QUINQUECUSPIS, F. v. M. var. villosa, Benth. (Anisacantha muricata, Moq.) var. villosa, Benth. "Spear-fruited Saltbush". (Chenopodiaceae).

Sedgwick, near Bendigo, E. J. Semmens. 24/10/1919; Numurkah Shire, per Department of Agriculture, Nov., 1919.

This plant is now evidently spreading eastward in Victoria, having been previously recorded from the North-West District only.

BRACHYCOME MICROCARPA, F. v. M. (Compositae).

Ti-tree Creek to Orbost, Mr. Sayer, 1887, Cann River, H. B. Williamson, Jan., 1918,

New for Victoria.

BROMUS CEBADILLA, Steud. "Chilian Brome Grass" (Gramineae).

East Caulfield, Geo. Seymour, 17/12/1919.

This grass, a native of Chili, may be classed as an exotic not yet sufficiently established to be considered naturalised.

BUCHANANIA OBLONGIFOLIA, W.V. Fitzg. Royal Society of W.A., III., p. 65, 1918. (Anacardiaceae).

A specimen from Robinson River, King's Sound, 1888, G. Poulton, was identified by Mr. Fitzgerald as B. oblongifolia before this species was published. It agrees with the specimens quoted in the Flora of the Northern Territory, pp. 171-172, as Buchanania Muelli var pilosa. The specimens hardly appear to be sufficiently distinct from the forms of Buchanania Muelleri to justify raising a new species, B. oblongifolia, W. v. F.

CALEANA MINOR, R. Br. "Small Duck Orchid" (Orchidaceae).

Sperm-whale Head, South-east of Lake Victoria, Gippsland, T. S. Hart, 12/12/1919.

This orchid has not been previously recorded so far east in Victoria.

CALOCHILUS CUPREUS, R. S. Rogers. "Copper Beard." (Orchidaceae)

A new orchid from South Australia, described by Dr. Rogers in the Proceedings of the Roy. Soc. of South Australia, collected for the first time in Victoria near Boronia Peak, Grampians, by J. W. Audas, 2/11/1918.

CALOSTEMMA PURPUREUM, R.Br. "Garland Lily."
(Hydrocharitaceae).

Lake Hattah, J. E. Dixon, April, 1919.
A definite locality in Victoria for this plant.

CASSYTHA. (Lauraceae).

In regard to the germination of seed of Cassytha, Mr. C. C. Brittlebank writes as follows:—

"About eleven or twelve years ago, at Myrniong, I obtained numbers of young seedling plants in all stages of growth from seeds just sprouting, rooted seedlings, and even plants, which had become fixed to young gum twigs. In several seedlings, which had reached this stage, the lower part had withered, but in some cases the plant had broken at the base. As to the conditions prevailing prior to and during the observations. A bush fire had passed through the stunted gum scrub, which was heavily loaded with Cassytha. Both host and parasite had been destroyed by the fire. Heavy rain fell shortly after, and continued to do so at intervals. The burnt gums sent out sprouts from their bases, and it was upon these young suckers that the more mature seedlings had become attached. This was the only time that I ever saw the seedlings of this plant, and it was due to this that I so carefully observed them." Evidently the germination of Cassytha is rare, owing to its hard seeds, and in this case the heat of the bush fire softened the seed coats and hence caused the absorption of water and germination of the seeds. The duration of the seeds in the soil is not known, but some buried in the soil of a pot for three years were found to be capable of germinating after being filed.

Mr. T. S. Hart has also forwarded me seedlings of C. melantha, found growing wild near Bairnsdale, in October, and apparently germinating naturally. It is possible that the difficulty of finding seedlings may be due to the fact that germination only takes place naturally during one month in the year, and that the rooted attachment is soon lost.

CASUARINA HELMSII. Ewart and Gordon, n.sp. (Casuarinaceae).

Gnarlbine, W. Australia, R. Helms, 12/11/91. Eucla, W. Australia, J. D. Batt, 1886. (See Plate XII.).

This plant was named C. humilis by Helms, but has terete instead of angular branches. The following is the description:—

A small tree from 5-8 feet in height. Branchlets are from 4-4½ in., and branches slender. The sheath-teeth vary from six to seven in number.

Fruit cones are cylindrical, and very regular, about ½-in. in diameter, and 1-in. long. The valves do not protrude beyond the surface, which is nearly smooth, and quite glabrous.

The seeds are small and red. They are much more pointed than those of C. humilis, and smaller.

Deviations from C. humilis,

(1) Branches.—These are much more slender, and the branchlets are about twice as long, though with shorter internodes and smaller diameter; they are also less angular than C. humilis. The colour of the branchlets is more greenish than grey.

(2) Fruits.—The cones are shorter and less rugose, the valves and markings are more regularly arranged, and the valves do not open as widely. The seeds are small, red and pointed, while those of C.humilis are larger, black and blunt.

Collomia coccinea, Lehm. ex Benth. "Scarlet-flowered Collomia." (Polemoniaceae).

Mandurang, Hintiraecku (without date), Bendigo, E. J. Semmens, Nov., 1919.

This plant, a native of Chili, is an exotic, found growing wild, but not yet sufficiently established to be considered naturalised.

Crepis setosa, Hall, f. "Hairy Crepis." (Compositae).

Ballarat, Victoria, E. J. Semmens, March, 1913.

This plant, a native of Europe and Asia Minor, may be classed as an exotic, not yet sufficiently established to be considered naturalised. It is a weed of cultivated and waste places, and takes up the place of useful vegetation, and should be suppressed.

Crowea saligna, Andr. (Rutaceae).

Pine Mountain, Upper Murray River, Vic., C. Walker, Oct., 1891.

Cytisus linifolius, Lam. "Flax Broom." (Leguminosae).

Roadsides, at Ararat, E. J. Semmens, October. 1918. Another locality in Victoria for this introduced plant.

ECHIUM VIOLACEUM, L., or Echium plantagineum, L.
"Paterson's Curse." (Boraginaceae).

After the last visit of the British Association some doubt was raised as to the correct name for the above plant, and it was even suggested that it might be Echium italicum. The latter suggestion was, however, merely due to the plant having been seen in fruit only. To decide the former question specimens were submitted to Dr. Lacaita, who has been specialising on the genus Echium. In his reply given beneath, the decision is made that the name given to the plant by Bentham in 1869, and under which the plant was proclaimed, is not correct, and that the name should be Echium plantagineum. As the point is one of some importance, Dr. Lacaita's reasons are given in full:—

"As to Echium plantagineum and Echium violaceum, the plant often called violaceum, especially by English botanists, is, as you rightly say, identical with E.plantagineum, but it is not E.violaceum,L. The violaceum of Sp. Pl. is a muddle of two species, quite unlike each other, neither of which is E.plantagineum. The synonyms all refer to E.rubrum, Jacq., a very distinct species. It is the only Echium with a clubbed instead of a trifid stigma. The definition of the genus both in Bentham and Hooker, and in Engler, requires modification in that respect. But the observation describes a plant cultivated in Hort. Uppslana, which is represented by the specimen in the Linnean Herbarium. This plant is neither rubrum, nor, as pointed out by Moris in his Flora Sardoa long ago, is it E.plantagineum (E.violaceum auctt, plur.). Moris says it is very like the Sardinian (and Italian) plant known as E. pustulatum S. and S. It is very like it, but as far as I can form an opinion without dissection of the corolla, which is inadmissable in Linnean type specimens, it is more probably the Portuguese and Spanish E. rosulatum, Lange, which, to this day, is grown at Kew, and taken under the misnomer of "E. plantagineum," or "E. creticum."

It is curious that Linneaus should never have recognised E. rubrum, for there are three fine examples of it in his herbarium, two sheets being loose, but the third is pinned to the sheet of E. italicum. None of these three sheets bears any writing of Linneus, who left them undetermined.

E. plantagineum is always easily recognised by—

1. Plantain-like basal leaves.
2. Amplexicaul upper leaves.
3. Peculiar thin texture of corolla in dried plant.

4. Corolla glabrous, with long hairs on the nerves and ciliate, not velvety pubescent all over, as in all species for which it could be mistaken.
5. Leaf indumentum homogeneous; the tubercle at base of hairs conspicuous or inconspicuous, but no carpet of close short pubescence beneath them.

It appears, therefore, that the name E. violaceum, under which Paterson's Curse was originally proclaimed, must now revert to E. plantagineum L.

EUCALYPTUS MITCHELLIANA. Cambage. Willow Gum. (Myrtaceae).

Near Chalet, Buffalo Mountains. An addition to the Flora of Victoria. The plant was originally named E. Mitchelli, but this name is already pre-empted for a fossil Eucalyptus (Journ. Royal Soc. of N.S. Wales, Vol. LII., p. 57, 1919.)

EUCALYPTUS WOOLLSIANA, R. T. Baker. (Myrtaceae).

About seventeen miles east of Nowingi Railway Station, North-West Victoria. (L. G. Chandler, 24/9/1919.)

This Eucalypt has not been previously recorded as growing indigenously in Victoria.

FICUS MACROPHYLLA, Desf. "Moreton Bay Fig." (Moraceae).

From the base of a large tree in the University grounds, in November, 1914, the bark was removed, and two inches of the outer wood. The tree attempted to send down roots from the cut surface at one point. These were cut off. During the first two seasons the foliage of the tree was quite normal. Later the leaves began to fall more rapidly than new ones were produced, and branch after branch died. During the first season the amount of latex increased markedly, after the second season it steadily decreased. The tree was not entirely dead until the declaration of Peace in May, 1919. It, therefore, lasted four and a-half years after being rung. During this time the wood remained moist and sappy to the heart of the tree, and it continued to grow on the upper part of the tree, above the ringing, but ceased to grow on the basal portion of the trunk. At the end of the four and a-half years the roots were found to be entirely dead, whereas above the ringing, the bark at one or two points still shewed signs of life. On examining the wood it was found that although the apparent rings

are regular and well defined, they are not annual rings. The tree could not have been planted more than fifty-five years ago, probably not more than fifty years ago. On some of the projecting buttresses the rings totalled from 220 to 263. The smallest number between the buttresses was 121. The tree can, therefore, form two to four rings in one year. These narrow rings are formed of alternate layers of wood fibres mixed with vessels, and of thin walled, rounded, almost parenchymatous cells resembling somewhat tangential medullary rays. If the cross section is examined from a distance sufficient to obscure the narrow rings, the broader annual rings can be distinguished. The number of these was 46, and in the buttresses they were broader and included more of the narrower rings.

The death of the tree was due not to any interruption of the water supply, but to the starvation and death of the roots. The wood of the Moreton Bay fig apparently retains the power of conducting water indefinitely, or at least, up to an age of 40 or more years.

Gleichenia Hermanni, R.Br. = G. linearis, Clarke. (Filicales).

As there are no Victorian specimens of this plant, it cannot be retained in the Flora of Victoria.

Gleichenia laevigata (Willd), Hook. (Filicales).

There appears to have been some confusion regarding the nomenclature of this fern. In "Hooker's Synopsis Filicum," G. laevigata is given as a synonym to G. flagellaris, Sprengl., but in Christensen's "Index Filicum," they are kept distinct. See also "Domin. Prod. Farnfl. Qld. 205. Rosenburgh, in his Handbook of Malayan Ferns, addopts G. laevigata, Hook, for the Malayan specimens. The typical G. flagellaris, Spreng. is a native of Mauritius only, whilst G. laevigata is a Malayan fern extending to Australia. Some specimens of G. laevigata have also been confused with G. flabellata, R. Br. — those labelled G. flabellata and given in Bentham's Flora Australiensis, Vol. VII., p. 698 (1878) under Victorian localities, proved to be G. laevigata, Hooker.

The distribution of G. laevigata, Hook, and G. flabellata, R. Br., in Australia, appears to be limited to the Eastern and Northern portion—i.e., Tasmania, Victoria, New South Wales, Queensland, and Northern Australia.

GNAPHALIUM INDICUM, L. "Indian Cudweed." (Compositae).

Near Station Peak, Victoria, without collector's name or date. This species has not been recorded previously for Victoria.

GOODENIA ARTHROTRICHA, F. v. M., ex Benth. Fl. Austr. IV. 62 (1869) =G. Bonneyana, F. v. M., Fragm. VI. 226 (1868), t. LIII.. (Goodeniaceae).

The above is given by Krause in Engler's Pflanzenreich IV., 277, p. 63 (1912).

The description of G. Bonneyana was published a year earlier than that of G. arthrotricha, hence G. Bonneyana has priority, and is therefore a valid species, with G. arthrotricha as a synonym.

Distribution.—Western Australia.

GOODENIA GENICULATA, R.Br. (Goodeniaceae).

K. Krause, in his Monograph of the Goodeniaceae, in Engler's Pflanzenreich IV., 277, pp. 52, 3, 4 (1912), divides the above species into five different species, i.e., G. geniculata, R. Br., G. primulacea, Schlechtd., G. robusta, Krause, G. affinis, De Vriese, G. lanata, R. Br. Of these some of the forms of G. primulacea cannot be readily distinguished from some of those of G. geniculata, hence G. primulacea can only be considered to be a variety of G. geniculata, i.e., G. geniculata, R. Br. var. primulacea, Benth, as given in Benth, Fl. Aust. IV., p. 63 (1869).

Krause gives the distribution of G. primulacea from South Australian localities only, but we have specimens from Victorian and New South Wales localities, which agree exactly with the above, and must be placed under the variety primulacea.

The distribution of the foregoing species are :—G. geniculata, R. Br., South Australia, Tasmania, Victoria, New South Wales, and Queensland.

G. geniculata, var. primulacea, Benth, South Australia, Victoria, New South Wales.

G. geniculata, var. heterophylla, F. M. Reader, Victoria.

G. robusta, Krause, South Australia, Victoria.

G. affinis, De Vriese, Western Australia.

G. lanata, R. Br., Tasmania, Victoria, New South Wales.

GOODENIA GRANDIFLORA, Sims. (Goodeniaceae).

In Engler's Pflanzenreich IV., 277, p. 75 (1912), Krause reduces G. albiflora, Schl., G. Chambersii, F.v.M., G. Macmillanii, F.v.M.,

and G. Nicholsonii, F.v.M., to varieties of G. grandiflora, Sims.

G. albiflora and G. Chambersii seem to be fairly distinct, and may for the present be classed as valid species.

G. Macmillanii and G. Nicholsonii may be placed as varieties of G. grandiflora, thus adding this species to the list of Victorian Flora.

Distribution.

G. grandiflora, Sims, Western Australia, South Australia, New South Wales, Queensland, Northern Australia.

G. grandiflora, var. Macmillanii, Krause, Victoria.

G. grandiflora, var. Nicholsonii, Krause, South Australia.

GREVILLEA RAMOSISSIMA, Meisn. "Branched Grevillea." (Proteaceae).

Buchan, East Gippsland, Miss Margaret McRae, 15/12/1919.

This plant has only been previously recorded from the North-Eastern districts.

GREVILLEA ROSMARINIFOLIA, Cunn. "Rosemary Grevillea." (Proteaceae).

Whipstick Scrub, Neilborough Road, north of Eaglehawk, Victoria, David J. Paton, 7/9/1919.

This species has usually reddish flowers, but the flowers of the above specimen were of a greenish yellow colour, but turned a dark colour when drying.

HAKEA FLEXILIS, F. v. M. "Flexile Hakea" (Proteaceae).

This is a valid species, and is a native of Victoria, New South Wales and South Australia.

HAKEA SERICEA, Schrad. (1795). (H. ACICULARIS, R.Br., 1809).

Hence H. sericea has priority over H. acicularis.

HELIPTERUM MICROGLOSSUM, Maiden and Betche. (Compositae).

As there are no Victorian specimens of this species, the name must be deleted from the Flora of Victoria.

HYBANTHUS FILIFORMIS, F. v. M. "Slender Violet." (Violaceae).

Mitta Mitta, S. F. Clinton, October, 1919.

Not previously recorded for the North-Eastern district of Victoria.

HYPOLEPIS TENUIFOLIA, Bernh. "Soft Hypolepia." (Filicales.)

Raymond Creek, near bridge of Old Cann Road, East Gippsland, George E. Harrison, 1/1/1917.

This is a definite locality in Victoria for this plant.

INULA GRAVEOLENS, Desf. "Stinkwort." (Compositae).

Nowa Nowa, Gippsland, Victoria, Hon. James Cameron, April, 1919. This proclaimed pest is gradually extending eastward in this State.

ISOPOGON ANEMONIFOLIUS, Knight. "Tall Conebush." (Proteaceae).

Near Providence Ponds, West of Fernbank Railway Station, Gippsland, Victoria, T. S. Hart, 15/11/1919.

A definite locality in Victoria for this plant. Although the plant is given in F. v. Mueller's Census, there were no specimens in the Herbarium, and Bentham gives it as from New South Wales only.

JASMINUM LINEARE, R. Br. "Desert Jasmin." (Oleaceae).

North-east of Lake Hattah, Vic., J. E. Dixon, April, 1919. A definite locality in Victoria for this plant.

LASIOSPERMUM RADIATUM, Trev. "Royal Down Flower." (Compositae).

Near Ballarat, H. B. Williamson, Feb., 1914.

This plant, a native of South Africa, has now apparently established itself as a naturalised alien in the above district.

LORANTHUS (Loranthaceae).

Hill's Northern Territory specimens No. 303 and 421, which were labelled Loranthus dictyophlebus, are considered by Mr. Maiden to be Loranthus Exocarpi, Behr. var. spathulata, Blakely; also Hill's No. 539, labelled L. longiflorus, Desr., he considers to be L. odontocalyx, F. v. M.

LORANTHUS LONGIFLORUS, Desr. "Long-flower Mistletoe." (Loranthaceae).

Genoa, Victoria, Rev. A. J. Maher, Nov., 1918.

New for Victoria.

LOLIUM SUBULATUM, Vis. "Wimmera Rye Grass." (Gramineae).

Nhill, January, 1919, A. J. Mullett.

This is a new record as a naturalised alien in Victoria. It is

stated to have spread from a patch planted near a dam twenty-three years ago at Minyip, and now covers several hundred acres. It has been found at various localities in the Wimmera, including Nhill, Warracknabeal, and has apparently been confused with some of the numerous forms of English Rye Grass, Italian Rye Grass, Western Wolths, etc.

It is a native of South Europe, but it does not appear to be common, or to have been investigated economically. Mr. Mullett informs me that it has a high carrying capacity for stock, maintains itself readily by seed, but is injurious to wheat cultivation. The grass appears to be more vigorous and larger in the Wimmera than in its native home. Hence specimens were sent to Professor Hitchcock, United States Agrostologist, who confirms the above identification.

It is possible that forms might be raised from this grass suitable for Central Australian regions, as a drought resistant grass. Information in regard to the properties of this grass is given by Mr. Mullett in the May number of the "Agricultural Journal of Victoria," 1919.

LONICERA JAPONICA, Thunb. (Caprifoliaceae).

Ararat Creek, Narnargoon, Victoria. J. W. Audas, Nov., 1919

A garden escape spreading along the creek and possibly in the process of naturalisation.

MICROCALA FILIFORMS, Hoff. and Link. "Slender Microcala."

Langwarrin, Victoria, Ed. E. Pescott, Oct., 1919.

A native of Europe, previously recorded as naturalised in the Western District of Victoria only.

MICROCYBE PAUCIFLORA, Turcz. (Rutaceae).

Localities.—Western Australia, Drummond, 5th Collection, n 209, South Coast, R. Brown, East Mount Barren, G. Maxwell.

South Australia.—Near Lake Hamilton, C. Wilhelmi; Port Lincoln, C. Wilhemi; Port Lincoln, S. S. Browne; Venus Bay, Col. Warburton; Kangaroo Island, O. Tepper.

Victoria.—N.W. of Lake Albacutya, C. French, senr.; Murrayville, H. B. Williamson.

MICROCYBE MULTIFLORA, Turcz. (Rutaceae).

Localities.—Western Australia, Drummond 5th Collection n. 211. North of Sterling Range, and west of Blackwood River, Muir; be-

tween Dundas Hills and Lake Lefroy, J. D. Batt; between Eucla and Fowler's Bay, Miss S. Brooke; Eucla, W. Webb, also J. D. Batt.

South Australia.—Moonta, Beythien, Kangaroo Island, O. Tepper; Sedan, Rothe.

Victoria.—Nhill, St. Eloy D'Alton; N.W. of Lake Albacutya and beyond Lake Hindmarsh, C. French; Mallee, C. Walter; Wimmera, C. S. Sutton, C. French, junr.

M. MULTIFLORA, var. baccharioides.

Near Fowler's Bay, W.A. E. Giles; near Port Eucla, W.A., Forrest; Gawler Ranges, S.A., Dr. Sullivan.

MICROCYBE ALBIFLORA, Turcz. (Rutaceae).

Locality.—Western Australia; Drummond, 5th Collection, n. 210.

The foregoing species were associated together by Baron von Mueller, under the heading of Eriostemon capitatus. The distinction of Microcybe from Eriostemon is not only a convenient one, but is based upon clear and definite scientific distinctions. Of the three forms included by Baron von Mueller under E. capitatus, all are valid as distinct species under Microcybe.

MURALTIA HEISTERIA, D.C. "African Furze." (Polygalaceae).

Norton's Summit, about eight or nine miles from Adelaide, Sth. Australia, per A. G. Edquist, July, 1919.

This hardy evergreen shrub, native of South Africa, is evidently a garden escape, and may become a pest if allowed to spread.

MYOSOTIS AUSTRALIS, R.Br. "Austral Forget-me-not." (Boraginaceae).

Wedderburn, Victoria, W. W. Watts, October, 1918.

A new locality in Victoria for this plant.

NOTHOSCORDUM FRAGRANS, Kunth. "Wild Onion or Scented Nothoscordum." (Liliaceae.)

Cawley's Creek, Timboon, per W. A. N. Robertson, 23/10/1919.

This plant, a ative of North America, recorded as a garden

escape in the Vict. Nat., XXIV., p. 193 (1905), may now be considered to be established as a naturalised alien in this State.

OXALIS PURPURATA, Jacp. (Oxalidaceae).

Drouin, Victoria, Nov. 1919, C. French, Junr.

Recorded previously as a garden escape, and now reported as common at Drouin. This plant, a native of South Africa, is evidently in process of naturalisation.

PANICUM PARVIFLORUM, R.Br. (Gramineae).

As there are no Victorian specimens of this plant, it must be deleted from the Flora of Victoria. Its original admission was due to an error. (See Vict. Nat. XXIV., p. 87, 1907.)

PHEBALIUM OBCORDATUM, Cunn. (Rutaceae).

Whipstick Scrub, Neilborough Road, North of Eaglehawk, Victoria, David J. Paton, 7/9/1919.

This species has only previously been recorded from New South Wales. There is a specimen in the National Herbarium labelled in the late Baron von Mueller's handwriting as Eriostemon Mortoni, from Sandhurst, Victoria, September, 1877, without collector's name. E. Mortoni, F.v.M., is a synonym to Phebalium obcordatum, Cunn. The Baron apparently neglected to record it for Victoria.

PHORMIUM TENAX, Forster. "New Zealand Flax." (Liliaceae).

Cawley's Creek, Timboon, per W. A. N. Robertson, 23/10/1919.

This plant, a native of New Zealand, which is often cultivated in gardens, is stated to be growing wild at the above locality.

PIMELEA FLAVA, R. Br. (Thymelaeaceae).

Bentham gives the flowers as being male and female. In Moore's Flora of New South Wales, this character is used in diagnosis in the Keys. In a large number of specimens recently examined in class it was noticed uniformly that each head contained a number of male flowers, and a few fruiting flowers, but that all the latter contained two well developed and apparently fertile stamens. The flowers may, therefore, be either male or hermaphrodite. There appears, however, always to be a larger number of male flowers in the head than of the "female," or hermaphrodite, flowers.

PLAGIANTHUS MONOICA (R. Helms M.S.). Ewart, n.sp. (Malvaceae).

Near Lake Deborah, West Australia. Collector, R. Helms, 1891.

This undescribed plant had the above MS. name, without any author. attached. It is a shrubby plant, covered with a pale, close, short tomentum, easily rubbed off or scraped off, leaving a brown surface on the branches. The leaves are long, narrow, sessile, nearly linear, with ventrally inrolled edges, 3-5 centimetres long, averaging about 2 mms. broad. The flowers are in terminal leafy cymes, usually of 3-6 flowers. Carpels, 3, rarely 2, one-seeded. Styles 3 (or 2) forking dichotomously into 6 (or 4) (Ureneae). Flowers male and female. Staminal column bearing anthers to the summit (Malveae). In the female flowers the petals are stiff, scarious scales covered with hairs. In the male flowers the petals are normal.

Although the character of the styles is peculiar, the plant appears to belong to Plagianthus, and it may be placed next to P. squamatus.

POLYPOGON LITTORALIS, Sm. "Perennial Beardgrass." (Gramineae).

Fisherman's Bend, Port Melbourne, Victoria, A. O'Brien, 18/11/1919.

This species is a native of Europe; has been recorded as introduced in Queensland and West Australia. It has now made its appearance in Victoria for the first time. In its native home it grows in salt marshes along the sea coast. It is not likely to prove of much value as a pasture grass.

PULTENAEA POLIFOLIA, Cunn. "Dusky Bush Pea" (Leguminosae).

Mitta Mitta, S. F. Clinton, Nov., 1918.

New for Victoria.

PULTENAEA PROCUMBENS, Cunn. "Curl-leaf Bush Pea." (Leguminosae).

Mitta Mitta, S. F. Clinton, Nov., 1918.

New for Victoria.

RANUNCULUS MUELLERI, Benth. "Felted Buttercup." (Ranunculaceae).

"Flourbag," Bright-Omeo Road, 4600 ft., Nov. 20, 1918, D. J. Paton.

In Mr. Williamson's paper on doubtful Victorian Plant records, it was pointed out that Ranunculus Muelleri was only represented in the Herbarium from the doubtful locality, Munyang Mts., which might mean a New South Wales locality. Mr. D. J. Paton forwards specimens collected on the Omeo side of Mt. Hotham, which belong to Ranunculus Muelleri, and, therefore, give an undoubted Victorian record for this plant.

SETOSA ERECTA, Ewart and Cookson. (Flora of the Northern Territory, 1917, p. 33) = SETOSA HORDEACEA, Ewart. (Chamaeraphis hordeacea, R. Br.)

The characters on which the distinction from Chamaeraphis are based are:—

Setosa:

Inflorescence a spike
Spikelets single to each awn
Glumes rigid
"Awn" very long and rigid
Styles free to the base
Staminodia 3 in female flower.
Outermost small glume callous and truncate

Chamaeraphis:

Inflorescence a panicle.
Spikelets two or more to each awn, very rarely one.
Glumes lax.
"Awn" short and soft.
Styles shortly united at the base.
Staminodia 2 in female flower.
Outermost small glume thin and membranous.

Setosa represents the highest development of the peculiar mode of developing an awned spikelet, of which the beginnings are shown in Chamaeraphis, and in Setosa the spikelet, with its basal branch "awn," disarticulates very readily and in one piece. In Chamaeraphis the spikelets disarticulate less readily and separately.

Setosa is strongly xerophilous, though usually growing near water. Chamaeraphis is semi-aquatic.

SOLANUM VIOLACEUM, R. Br. "Violet Nightshade." (Solanaceae).
East Gippsland, Rev. A. J. Maher.
New for Victoria.

TRICHINIUM ALOPECUROIDEUM, Lindl. "Long Tails." (Amarantaceae).

"Lorquon" received from State School, No. 2590, 5/5/1919. A definite locality in Victoria for this plant.

TRICHOMANES PARVULUM, Poir. (Filicales).

There are no Victorian specimens of this fern. The plants on which the original record was made proved on examination by the Rev. W. W. Watts to be *Umbraculum flabellatum*, Gottsche (Hepaticae) the two plants having an extraordinary external resemblance. T. parvulum must be deleted from the list of the Flora of Victoria.

TRIGLOCHIN CENTROCARPA (Hook) var. longicarpa. (Naiadaceae).

Watheroo Rabbit Fence, W.A., M. Koch, September, 1905.

According to Ostenfeld, in Dansk Botanist, Arkiv. Bd. 2, page 35, 1918, the above was included under Triglochin centrocarpa, Hooker, in the collection by Max Koch.

ULMIS CAMPESTRIS, L. "Common Elm." (Ulmaceae).
(Rate of growth.)

In the last number of the Contributions to the Flora of Australia, some data were given in regard to the growth of this tree. One curious feature was an apparent contraction taking place during autumn and winter, after the cessation of growth in circumference, followed by an expansion during a wet winter period (June-July). In these observations the bark was left untrimmed around the measurement line, and the tape used was standardised only at the commencement and close of the observations. According to Trowbridge and Weil (Science N. Series 48, 1918, pp. 348-550), trees vary both in length and in breadth according to the temperature. Thus stems of Tilia europaea and Platanus orientalis increase in diameter slightly with a rise of temperature above 32 deg. F., but undergo marked transverse contraction with a fall of temperature below 32 deg. F. They conclude that the diameter of a tree is less when frost cracks are open than when they are closed, and that the cracks are due to this contraction and not to the expansion of the frozen water. The question naturally arises whether full precautions were taken to ensure that the measurements taken were adequately standardised. Trowbridge and Weil mention that

the changes in circumference lag six to twenty-four hours behind the changes of temperature. The temperature at the centre of the trunk of a large leafless tree is not, however, affected appreciably by daily variations of temperature, and only responds slowly to a change in the average mean temperature.

In the measurements of the Elm taken in 1917-18, it was found that an apparent growth contraction took place in winter, and that slight variations in circumference were shown from time to time during the non-growing period. These measurements were taken with a tape around a partially smoothed line.

To obtain more accurate measurements a girdle of bark was removed, leaving a smooth surface close to the cork cambium. A standard length of 6 ft. 9 in. was marked by Dr. Baldwin, Government Astronomer, on the stone basement. After each measurement with a waxed tape it was extended over the standard, the increase over the standard giving the actual increment of growth. The tape was thus merely used to transfer the circumference of the stem to the standard length, and not to measure it.

The tape was kept in a dry room, and from November, 1918, to April, 1919, 6 ft. 9 in. on the tape corresponded to 6 ft. 9 in. on the standard. The tape then began to shorten, and most rapidly during May, until 6 ft. $9\frac{4}{16}$ on the tape covered 6 ft. 9 in. on the standard, and on June 15th, 6 ft. $9\frac{5}{16}$. By July 2nd the tape had shortened a further $\frac{1}{32}$ of an inch. A similar tape kept in a damp cellar for a month shortened $\frac{1}{4}$ inch per 8ft. in this time, although the temperature was fairly constant. The effect is, therefore, due to the gradual absorption of moisture, the humidity of the air increasing greatly in Melbourne during winter.

The deepening of the girdle on the tree reduced the circumference from 6 ft. $11\frac{1}{4}$ in. to 6 ft. $8\frac{3}{4}$ in.

In the previous year's measurements growth did not become perceptible until the first week in November, but here it began during the first week of October. This was the same time as when the cambium began to divide in the previous years measurements, so that the removal of the cork ring allows the actual growth to become sooner perceptible externally. In 1918 growth ceased at the end of February, but in 1919 it continued until the middle of March. This was probably, however, the result of the exceptionally mild and favourable autumn experienced in 1919. The total growth in 1917-1918 was $1\frac{1}{4}$ in., and in 1918-1919 $1\frac{1}{2}$ in.

Date.	Corrected Girth.			Rate of Growth per month of 30 days in $\frac{1}{16}$ in.
	Ft.	in.	$\frac{1}{16}$ in.	
July 26, 1918	6	8	12	nil.
August 16, 1918	6	8	13	nil.
September 21, 1918	6	8	13	nil.
October 10, 1918	6	8	14	
October 18, 1918	6	8	14	1.5
October 30, 1918	6	8	15	2.5
November 7, 1918	6	9	1	7.5
November 26, 1918	6	9	5	6.3
December 3, 1918	6	9	7	8.6
December 14, 1918	6	9	9	5.5
December 26, 1918	6	9	11	5.0
January 17, 1919	6	9	14	4.3
January 30, 1919	6	10	0	4.6
February 20, 1919	6	10	3	4.3
March 13, 1919	6	10	5	2.9
March 28, 1919	6	10	5	nil.
April 25, 1919	6	10	5	nil.
May 21, 1919	6	10	5	nil.
August 1 1919	6	10	5	nil.

Throughout the autumn and winter there was no evidence of any expansion or contraction with changes of temperature within a range of 45°F., (34°F.-79°F.), the static measurement being 6 ft. $10\frac{5}{16}$ in. On several occasions after rain had fallen and saturated the bark, corrected readings of $6.10\frac{6}{16}$ were given (May 23rd, June 2nd, June 15th, June 30th, etc.), but between these times the measurement reverted to 6 ft. $10\frac{5}{16}$ in. It would be of interest to know in detail the method of standardization adopted by Trowbridge and Weil, and also what precautions were taken to distinguish between variations of girth due to moisture and those supposed to be due to temperature. A variation of $\frac{1}{16}$ in. in 6 ft. $10\frac{5}{16}$ in. is approximately 0.07%, and if it were due to temperature, with a range of 45°F., it would represent 0.0017% per 1°F., which would in any case be negligable in dealing with a material like the trunk of tree. The view put forward by Trowbridge and Weil that frost cracks are due to the pronounced contraction of the diameter of the tree and not to the expansion of frozen water merits further investigation.

VERBASCUM BLATTARIA, L. Spurious or Twiggy Mullein. (Scrophulariaceae).

In J. M. Black's Naturalised Flora of South Australia Ver-

In J. M. Black's Naturalised Flora of South Australia Ver-
ralised aliens in South Australia, whereas in Victoria the only two

recognised are V. Thapsus and V. Blattaria. There has always been some confusion between V. Blattaria and V. virgatum. Thus Verbascum virgatum, Spreng. (Syst. 1, 621)=V. Blattaria.

Verbascum Blattaria, Vell =V. virgatum.

The true V. Blattaria is that of Linnaeus Sp. Pl. 178, a native of Europe and Asia, whereas V. virgatum was described by Stokes (With. Bot. Arr. Brit, Pl. ed. 11, 227), and appears to be originally a native of Europe only.

In Bentham's British Flora, V. virgatum is distinguished from V. Blattaria by (1) the more abundant glandular hairs, (2) the pedicels of the flowers are shorter than the calyx, whereas in V. Blattaria they are longer; (3) there are usually 2-6 flowers to each bract.

If the Victorian specimens of V. Blattaria are sorted out into those with long and those with short pedicels, it will be found that the glandular pubescence varies in both series, and that there are as many specimens of "V. virgatum," with one flower to each bract, as with two or more flowers. If the specimens are sorted into "1 flowered," and 2, or more, flowered specimens, the long stalked and short stalked characters are completely mixed in both sets. Although V. virgatum is called the "Twiggy Mullein," branching specimens otherwise typical of V. Blattaria are quite common.

The only satisfactory conclusion is to regard V. virgatum as a variety of V. Blattaria, differing in one constant feature, the length of the pedicel, as thus—

V. Blattaria, L.	V. Blattaria, L. var. virgatum.
Flowers 1 to each bract Pedicels longer than calyx or bracts.	Flowers 1 or 2 rarely up to 6 to each bract. Pedicels usually shorter than calyx or bracts.

The variety virgatum is the commoner form in Victoria, but in Europe is of more restricted range than the typical V. Blattaria.

VICIA SEPIUM, L. "Bush Vetch." (Leguminosae).

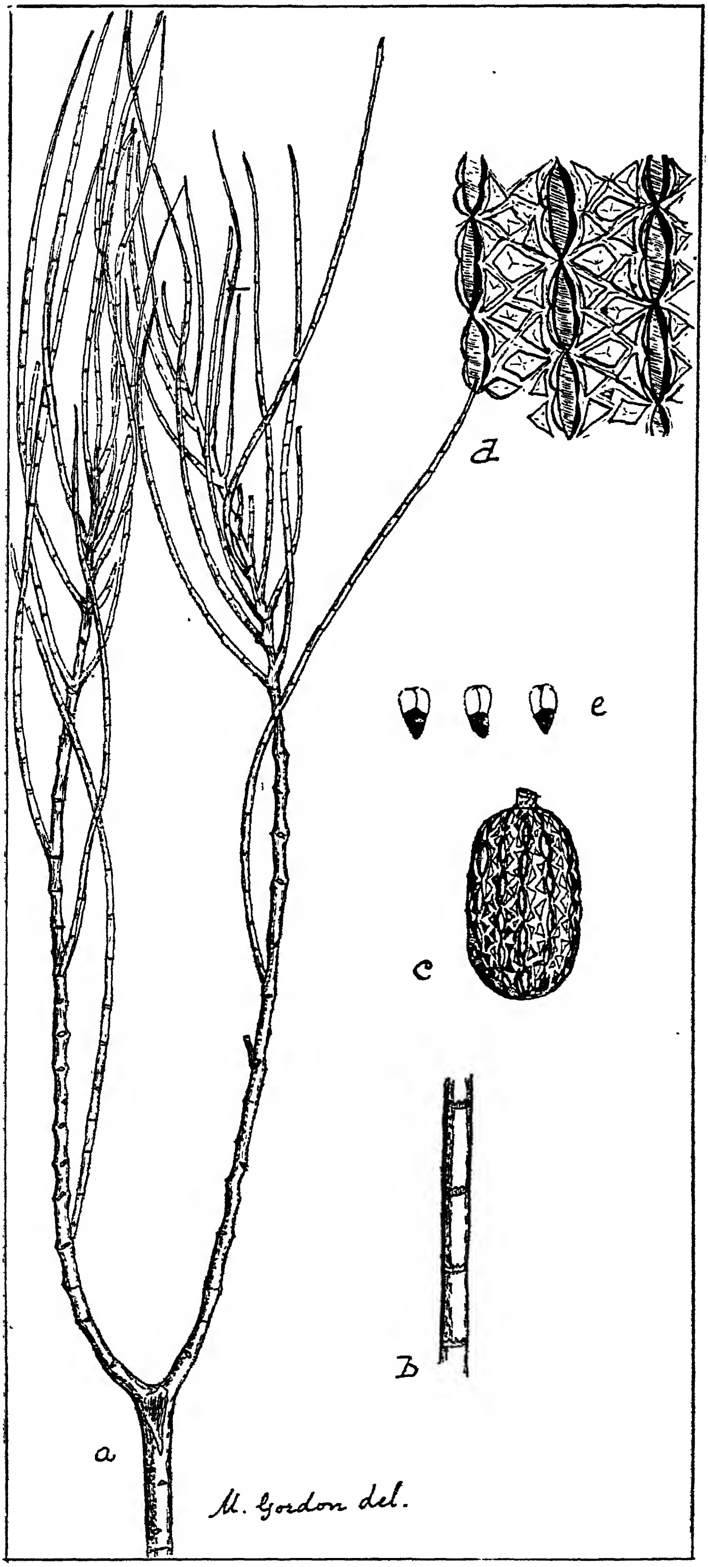
Alston's Farm, S. Wycheproof, Vic., W. W. Watts, Sept., 1918.

Not previously recorded as a naturalised alien in Victoria, but probably often confused with Vicia sativa. Vicia sepium is naturalised in South Australia.

ZYGOPHYLLUM BILLARDIERI, D.C. "Coast Twin Leaf." (Zygophyllaceae).

Wahgunyah, Murray River, G. H. Adcock, Sept. 11, 1919.

In the preparation of phylloxera resistant vines by grafting on



Casuarina Helmsii, n sp

to resistant stocks, the grafts are at one stage packed in seaweed trucked from the coast, and washed at Wahgunyah. This has caused the appearance of several coastal plants at this inland locality, including the above, as well as Melilotus parviflorus and Salsola Kali.

DESCRIPTION OF PLATE XII.

CASUARINA HELMSII, Ewart and Gordon.

(a) Portion of branch.
(b) Branchlet with leaf-sheaths.
(c) Fruiting cone.
(d) Portion of same, magnified.
(e) Seeds.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920.]

ART. XV.—*A revision of the genus Pultenaea, Part 1.*

BY. H. B. WILLIAMSON.

(With Plates XIII., XIV. and XV.).

[Read November 6th, 1919].

It is only natural that in large genera more confusion is likely to occur than in small ones, and some time ago Professor Ewart advised me that a general revision of the genus Pultenaea would probably yield profitable results, and was indeed urgently necessary. The results of the first part of this investigation, based on the examination of the material at the National Herbarium, Melbourne, and of specimens received from the Government Botanists of the other States, are here given.

The genus Pultenaea is confined to Australia, and comprises 92 acknowledged species. Seventy-five species are described in Bentham's Flora Australiensis, two of which have been transferred to other genera, and one reduced to a variety. The species since described number 20, comprising those set up by Mueller (3), Tate (2), Black (2), Maiden (3), Maiden and Betche (2), Bailey (1), Baker (2), Scott (1), Andrews (1), Pritzel (1), and Regel (1). No labelled specimen of either of the last three is in the Herbarium.

The approximate distribution is—Queensland, 11 species; New South Wales, 45; Victoria, 37; Tasmania, 13; South Australia, 22; and Western Australia, 22.

About half of the species are confined to one State; about 20 are recorded for two States, 10 for three States, and 6 species are widely spread—four States. As with other genera, few of the Western Australian species—two—occur east of the limits of that State, one of which extends to South-West Victoria. It is worthy of note that in the Flora of the Northern Territory, Ewart and Davies, 1917, the genus is not mentioned, and that very few records of Pultenaea exist for Western Australia outside the south-western district of that State.

While attempting a revision of the genus in which, judging by evidence of labelled and unlabelled specimens in the National Herbarium, much confusion exists, it is not claimed that finality can now be reached with regard to certain groups, for the occurrence of forms that seem to connect the members of those groups presents much difficulty. Considering the varying forms for example, of the group known under Eupultenaea, an advocate for

reduction of species could place five or six, including P. stricta, P. retusa, P. Gunnii, under one species name, and cultural experiments may yet prove that they are not all valid species, but few would be bold enough to make such a drastic reduction.

Even if it were proposed to unite, say, the three mentioned, which certainly are very close as regards floral structures, the work of the great systematists, Bentham, Smith, Hooker, Mueller and others, would be discredited, and their ideas of what constitute a species set at naught. While recognising most of the species set up by these great workers, one's aim must be to realise their system, and to follow it in the light of later discoveries of forms unknown to them. At the same time it is inevitable that in all such revisions of large genera, additional species must be set up, consisting for the greater part of certain forms which have in error or for convenience been placed as varieties, but which, if they had been more fully considered by the pioneers of systematic botany, would have been given specific rank. The author, recognising the fallacy of multiplying species unnecessarily, has in doubtful cases allowed the varietal rank to stand. It is known that species may show variations according to climatic and soil conditions, and it may be conceded that the variations will be greatest or most likely to occur in the first named, and least in the last-named of the following:—Habit; colour of flower; size, shape and texture of leaf; size and shape of stipules; arrangement of flowers; size and shape of bracts, bracteoles, calyx, ovary and seeds. So that in the case of Pultenaea a variation of ovary, whether stipitate or sessile, villous or glabrous, shape of calyx, position and shape of bracteoles and bracts, are of more importance in determining a species than the habit, the shape and size of the leaves, or the colour or size of the corolla. In other words, if ovary, calyx, bracteoles and bracts are similar, a good deal of variation in habit or in leaf can be allowed within the limits of a species, whereas if habit, leaves, corolla and stipules are similar, a marked difference in the reproductive organs just named will justify the setting up of a species.

In the diagnostic drawings this has been kept in view, and they include besides sketches showing shape and size of leaves and stipules, drawings showing only the shape, size and relative position of calyx, bracteoles and bracts. No attempt is made to show the marginal curving of the leaf, or the nature of the indumentum.

Regarding the corolla, one has only to read in descriptions the oft-repeated "Standard twice as long as calyx," or "nearly

twice," "lower petals shorter"—this, by the way, is included in the description of the genus—"keel dark coloured," etc., to feel how unimportant these parts are in determining a species of the genus. The fact that so many species of Pultenaea have been described in the absence of pods seems to show that these are non-essential, though in the case of a plant without stipules, and with the bracteoles well away from the calyx tube, the examination of ripe seeds would be necessary to determine the genus.

Section EUPULTENAEA.

Pultenaea daphnoides, Wendl.

Varies much in foliage, the normal plant having leaves cuneate-oblong, with a fine straight point. Flowers in dense terminal heads, and bracteoles well up on the calyx

var. obcordata Bth. has truncate leaves with a prominent point. Victoria, Tasmania, South Australia.

var. parviflora, n.v.

This has been placed under daphnoides and retusa, and among doubtful forms. It differs from the type in having cuneate-oblong leaves 4 to 6 lines long without a point, margins flat or slightly incurved, mid-rib obscure above.

Upper Murray district, C. French, Junr., 1886. Wildflower Show, 1919, no loc.

Pultenaea stricta, Sims.

A smaller shrub than P. daphnoides, with smaller leaves, ovate-oblong, with recurved margins, and a small recurved point. Bracts numerous, glabrous, deciduous, with rounded point, outer ones bifid and shorter. Bracteoles high on the calyx, usually glabrous. I can find no constant variation from the type in var. incurvata, Ewart, from Frankston.

Pultenaea Maidenii, Reader.

This differs from P. stricta in its long-pointed hairy bracteoles, fixed near the base of the calyx. The lower lobes are narrow, longer than the tube, and almost setular pointed. The leaves are cuneate, thin and often conduplicate. Its nearest affinity is P. largiflorens, F.v.M.—the broad-leaved form from South Australia—from which it differs in having narrower cuneate leaves and a very different calyx. It should retain specific rank.

Pipe Head Waterworks, Hamilton, Vic., Collected by the writer, 11/1904.

Pultenaea capitellata, Sieb.

A species bearing a remarkable general resemblance to P. pycnocephala, F.v.M., and variously placed with that species, or with P. stricta, in which latter Bentham wrongly included it.

Its minute stipules and high-adnate bracteoles place it right away from Mueller's species, although there is a specimen labelled by him "P. pycnocephala F.v.M." From P. stricta it can be separated by its flower heads, solid and almost globular, and very persistent bracts, broadly ovate, densely covered with silky hairs, except at the margin, bifid, with a narrow median point. Calyx lobes and bracteoles are setaceous. Leaves cuneate, slightly pointed. The specimen, "Port Jackson, Sieb, n. 313," Fl. Aust., p. 113, is this species, and not the plant figured by Sims, Bot. Mag. Sieber's name should be retained for it.

Braidwood District, Twofold Bay, N.S.W., and East Gippsland, Vic.

Pultenaea pycnocephala, F. v. M.

A remarkable species, with broadly-ovate coriaceous leaves, silky below, and with flowers in dense globular heads, covered with imbricate, silky villous, persistent bracts. The bracteoles are long, very silky, villous, and are fixed quite under the calyx.

Bluff Mount, Poverty Point, Tenterfield, N.S.W.

Pultenaea retusa, Smith.

A species with calyx and bracteoles like those of P. stricta, but with shorter bracts, more falcate upper calyx lobes, and leaves linear to cuneate, sometimes emarginate.

Var. linophylla, Benth, with longer leaves and longer calyx. Port Jackson.

Var. longifolia, F.v.M., with leaves up to 1½ inches.

Specimens from E. Gippsland, with cuneate leaves, almost bilobed, 2 or 3 lines long, seem to be included under the description in Bentham.

Specimens from Hazelbrook, N.S.W., Hamilton, and from Twofold Bay, show leaves cuneate-oblong to obovate.

Queensland. New South Wales and Eastern Victoria.

Pultenaea Benthami, F.v.M.

Recorded only from the Grampians, Vic., with calyx, bracts and bracteoles like those of P. daphnoides, but with rigid, almost linear, acute, or pungent leaves.

Pultenaea Millari, Bailey.

A species with silky cuneate-ovate leaves, and flowers solitary in the upper axils.

Stannary Hills, Herberton, Qld.

var. *angustifolia*, n.v.

From Eidsvold, Qld., Dr. Bancroft, are specimens, which differ only from the type in having leaves narrow-lanceolate, with a more prominent point.

Pultenaea myrtoides, Cunn.

With leaves like those of P. Millari, but nearly glabrous. Flowers are in dense terminal, globular heads, with boat-shaped bracteoles fixed rather low on the calyx.

New South Wales, Queensland.

Pultenaea polifolia, Cunn.

A Queensland species, with hairy linear leaves, and remarkably long petioles, and with bracteoles linear-subulate, fixed about the middle of the calyx tube. Flowers in dense terminal heads.

Pultenaea petiolaris, Cunn.

A species with leaves linear to lanceolate, with a point slightly recurved. Its calyx lobes are fringed with silky hairs, as are also the keeled bracteoles fixed well up on the calyx tube.

Pultenaea mucronata, F.v.M.

=*P. polifolia*, Cunn, var. *mucronata*.

This plant was described from specimens from Ovens River, Vic., and differs from P. polifolia only in having broader leaves, more villous branchlets, and less keeled bracteoles set rather lower on the calyx tube. Bentham says, "This may possibly prove to be a broad-leaved form of P. polifolia." In the light of evidence of intermediate forms, including those from Batlow and Nungatta, N.S.W., the species name, mucronata, can be suppressed, and all the forms included under P. polifolia.

Specimens from Blackheath, N.S.W., with cuneate mucronate leaves, and setaceous bracts, stipules and calyx lobes, can provisionally remain under var. mucronata.

Pultenaea Gunnii, Benth.

Although very variable in foliage, the small size of the calyx, bracts and bracteoles, and the constantly recurved edges of the leaves, keep it quite distinct from P. stricta. "The larger leaved forms can always be distinguished from P. striata (stricta?) by the very much smaller bracts," (Bentham). These are scarcely ever longer than the very short pedicels, and the bracteoles are minute, of a dark colour, and set well up on the calyx. As regards flowers, it is nearest to P. microphylla, but that species has cuneate to linear-cuneate leaves.

var. planifolia, F.v.M., a broad leaved form from Badger Head, Tas.

var. flava, Ewart, from Wandin, Vic., has light yellow flowers.

One or two forms which seem to connect this with P. stricta remain for further study,

Pultenaea microphylla, Sieb.

A species from New South Wales, with linear-cuneate leaves, and a smaller calyx than the last-named species. Tenterfield specimens have almost linear leaves, with lower face almost closed.

var. cuneata, Benth; leaves are cuneate-truncate, 3 to 4 lines long, bearing some resemblance to P. largiflorens, F.v.M., which latter may be distinguished by the large upper lip of its calyx.

New South Wales, Queensland.

Pultenaea cinerascens, Maiden and Betche.

=*P. microphylla* var. *cinerascens.*

As the only difference between this plant and P. microphylla, Sieb, is that of habit and foliage, it should not have received specific rank. Specimens of P. microphylla from Tenterfield show almost linear leaves. In Proc. Roy. Soc., N.S.W., XXXIII. 310, the authors admit that there is no marked difference of flowers or inflorescence, and that Gilgandra and Scone specimens are links connecting the two alleged species. All these forms can now well be grouped under Sieber's species name.

Warialda, N.S.W.

Pultenaea Drummondii, Meiss.

A Western Australian species, with shining yellowish scarious bracts, and a peculiar calyx, with upper lobes rounded, and united into a broad emarginate lip.

Pultenaea Skinneri, F.v.M.

A Western Australian species, with recurved mucronate leaves, reversed on the stem, and with a large calyx 4 lines long, with bracteoles nearly as long, fixed well below the calyx tube.

Pultenaea Hartmanni, F.v.M.

A Queensland species, with leaves between those of P. scabra and P. retusa, but with minute stipules, remarkably small bracteoles fixed at the base of the calyx, and with longer calyx lobes than those of P. retusa.

Pultenaea pinifolia, Meiss.

A Western Australian species, with narrow linear leaves, spreading stipules, and very deciduous bracts and bracteoles, the latter being long, and fixed well below the calyx tube.

Pultenaea pedunculata, HK.

A prostrate shrub often matted, with flowers on filiform pedicels, often half inch long—in some Port Lincoln specimens one inch long. The calyx is almost glabrous, with acuminate lobes, and the bracteoles are nearly as long, linear and below the calyx tube.

South Australia, Victoria, New South Wales, Tasmania.

[As there is some discrepancy between the description of this species in Bentham's Flora, and that given in the Botanical Magazine, the matter will be discussed when dealing with Pultenaea Ausfieldii, Regel, one of the forms that appear to have been included under P. pedunculata].

Pultenaea conferta, Benth.

A Western Australian species, with short, linear, crowded leaves, and a remarkable calyx, with the upper lobes large and free, and the lower ones very much smaller.

Pultenaea pauciflora, Scott.

A Western Australia species, with long white hairs on the young foliage, and with incurved leaves linear-lanceolate, flat, but with

thickened or slightly recurved margins, with mid-rib scarcely prominent below, fine pointed. The calyx has equal lobes, and the bracteoles are free from the calyx. It belongs to section Empultenaea, near P. Drummondii.

Narrogin Exp. Farm, Stoward.

Pultenaea scabra, R.Br.

Three very divergent forms have been united by Bentham in this species:—

(a) R. Brown's P. scabra, from the Blue Mountains (Sieb, n. 286), with narrow-cuneate, truncate leaves, with a fine seta terminating the mid-rib, and with setaceous, spreading stipules, sometimes 3 lines long.

(b) Lindley's P. montana—P. scabra var. montana Bth.—the common Victorian form, with minute stipules, and leaves obcordate or obvate, with no point, often with much recurved margins.

(c) R. Brown's P. biloba—P. scabra var. biloba, Bth.—with leaves dilated and two lobed, with a short recurved point.

Brown's scabra and Lindley's plant are very distinct, but as there is no marked difference in the flowers they may be kept under P. scabra, especially as the varying forms of the var. biloba present graduated intermediates.

Section ACIPHYLLUM.

This section—3 species—is confined to Western Australia, and is distinguished by peculiar transversely reticulate leaves.

Pultenaea aciphylla, Benth—(P. recticulata Bth.)—with leaves ovate to linear-lanceolate, pungent. *Pultenaea aspalathoides*, Meiss, with leaves narrower than those of P. aciphylla, with a smaller calyx, larger bracteoles, and flowers crowded round with leaves.

Pultenaea ochreata, Meiss, distinguished from the two former by having shorter and broader leaves, with no point, and nearly orbicular bracteoles.

Section EUCHILUS.

This section contains those species which have ternate or opposite leaves.

Pultenaea obcordata, Benth.

A West Australian species, with obcordate, ternate, or opposite leaves, and a remarkable calyx, with its upper lobes almost orbicular, and its lower lobes linear and much shorter.

Pultenaea rotundifolia, Benth.

A West Australian species, with minute opposite leaves, rarely crowded, and flowers like those of P. obcordate, but on filiform pedicels often half-inch long.

Pultenaea calycina, Benth.

A West Australian species, with opposite or ternate leaves, like those of P. retusa, and with a calyx resembling that of P. obcordata, but with larger, more separated upper lobes.

Pultenaea acuminata, R. T. Baker.

A New South Wales species, with opposite leaves resembling those of P. Gunnii, with a very large calyx—about 4 lines—with a short tube, and long linear bracteoles fixed below the calyx tube.

Byalong Creek, N.S.W.

Pultenaea spinulosa, Benth.

A West Australian species, with opposite, crowded pungent leaves, reticulate below, and with a calyx having large, almost free, upper lobes, having subulate points, and with very narrow lower lobes.

Pultenaea tenella, Benth.

An Alpine species, with the habit and appearance of P. paleacea var. sericea, but having ternate, concave leaves, and a long calyx with lobes longer than the tube.

Alps of Victoria.

Pultenaea Luehmanni, Maiden.

A slender trailing plant, remarkable for its filiform, opposite branchlets, and distant leaves. Its terminal, head-like inflorescence distinguishes it from all other species of the section. Its nearest affinity is P. tenella, but that species has axillary flowers, and a larger and a differently shaped calyx.

Pipe Head, Hamilton Waterworks, Vic., Collected by the writer, Nov., 1904.

Pultenaea cymbifolia, J. M. Black.

A South Australian species, with small, decussate, convex mucronate leaves, rather crowded, and a silky calyx like that of P. calycina, with large upper lobes, united below the middle, and very small subulate lower lobes.

Kangaroo I., Andrews. A specimen was sent to the Herbarium in 1886 by Miss Brookes, Mt. Rugged to Victoria Springs, but was set aside by Mueller for determination later.

Section COELOPHYLLUM.

This section includes those species with alternate leaves, flattened, concave or terete.

Pultenaea flexilis, Smith.

An almost glabrous shrub with flat, or slightly concave leaves, glabrous calyx, with scarcely pointed lobes shorter than the tube, flowers axillary on rather long pedicels, with lanceolate, pointed bracteoles fixed on the tube at the base, and ovary glabrous with a few long hairs at the top.

Victoria, New South Wales.

Specimens from Clarence River, Beckler, are labelled "P. flexilis var. mucronata," p. 135, Fl. Aust. They exactly match specimens from Giggo Range, and the Dandenongs, Vic., since determined by Mueller as a variety of P. juniperina. These, as well as specimens from Pine Mount, N.E. District, Walter, having pubescent ovary, and bracts and bracteoles of P. juniperina, must be referred to that species.

Pultenaea altissima, F.v.M.

A species which has been wrongly united with P. flexilis, from which it differs in having its bracteoles ovate and free from the calyx, in which characters it agrees with P. obovata Benth., its nearest affinity. It has also its flowers in terminal umbel-like racemes, not axillary as in P. flexilis, and its leaves are linear-cuneate without points, and rarely over half-inch long. From P. obovata it differs in having a much smaller calyx with shorter lobes, and leaves narrower. We should follow Bentham in keeping it a distinct species.

New South Wales, Twofold Bay, and Upper Genoa River; probably occurs in East Gippsland.

Pultenaea obovata, Benth.

A New South Wales species, like P. flexilis, but with broad-ovate or broadly-cuneate leaves, two or three lines long, on rather long petioles, concave, light green above. Calyx, with lobes longer

than the tube, which distinguishes it from P. altissima, and with small ovate-orbicular bracteoles fixed below the calyx.

Moona River, Walcha, N.S.W.

Pultenaea paleacea Willd.

A species with linear leaves, long, scarious stipules, and dense terminal heads much covered with long imbricate bracts. The calyx is silky, and bracteoles are ovate, and are fixed on the calyx tube. Port Jackson, var. obtusata, Benth, has broader cuneate, leaves; var. sericea, Benth, the form common near Melbourne, has long, silky, white, scarious stipules and bracts.

Var. robusta, n.v. from Queensland (Gympie, Wellington Point), is a robust plant, differing only from var. sericea in having much larger leaves and flowers.

Pultenaea Williamsoni, Maiden.
= *P. paleacea*, var. *Williamsoni*.

This plant must now be referred to P. paleacea. It is of stronger and more robust growth, though of the same habit. The bracteoles are certainly wider and longer than in P. paleacea, but they are not constantly fixed at the very base of the calyx, being often just above the base. There are specimens from Wellington Point, Q., J. Wedd, which match the Victorian specimens in every respect, except that the bracteoles are smaller, and are fixed rather higher on the calyx tube.

From P. stricta this plant is far removed by its habit, its remarkably large stipules, its large leaves, its large persistent bracts, and the shape and position of its bracteoles.

Strathbogie, Vic., A. W. Vroland, Nov., 1904.

Wellington Point, Q., J. Wedd.

Pultenaea stipularis, Smith.

A showy New South Wales species, easily distinguished by its straight, linear leaves, and very long stipules, calyx lobes, bracts and bracteoles, the two last-named being hirsute with long hairs.

Port Jackson, Blue Mountains, N.S.W.

Pultenaea glabra, Benth.

A New South Wales species, with leaves like those of P. dentata, and with few bracts. It can readily be distinguished by its peculiar calyx, and the absence of all hairs. The calyx has nearly equal

lobes, acute and spreading, as long as the tube. Bracteoles broad-lanceolate fixed at the middle of the calyx tube.

Blue Mountains, N.S.W.

Pultenaea dentata, Labill.

A widespread species, with narrow-lanceolate concave leaves, and imbricate bracts, covering the dense heads in bud. The species is easily determined by its bracteoles, which are ovate or oblong, bifid, with a central subulate lobe, giving the summit a dentate appearance.

New South Wales, Victoria, Tasmania.

Pultenaea subumbellata, HK.

A species with heads more capitate than subumbellate, and flat or slightly concave leaves, and a small hairy calyx, with hairy bracteoles well under the calyx. This last character, along with the absence of stipules, makes it a connecting link between Pultenaea and Latrobea diosmifolia, Bth. It has, however, strophiolate seeds.

New South Wales, Victoria, Tasmania.

Pultenaea incurvata, Cunn.

Like P. subumbellata in the absence of stipules, and the position of bracteoles, but distinguished from that species by its generally larger leaves, incurved at the tips often wrinkled below. Its bracts and bracteoles also are larger. Brown's specimens from Port Jackson are not incurvata, as labelled, but subumbellata.

New South Wales only.

Pultenaea selaginoides, F.v.M.

A Tasmanian species allied to P. subumbellata, having very minute stipules, shorter, thicker, and more concave leaves, almost imbricate. The calyx is small and glabrous, with blunt and almost equal lobes. Bracteoles are lanceolate, concave, fixed under the calyx. Flowers axillary, not capitate, as in P. subumbellata.

St. Paul's River, Tasmania.

Pultenaea euchila, D.C.

A plant that looks like a large form of P. flexilis, having larger flowers and leaves, and longer pedicels. It differs from P. flexilis in bracteoles, and calyx, the former being linear-subulate, and

inserted close under the calyx, and the latter being larger, with lobes longer than the tube, with the upper ones falcate.

Port Jackson, Hunter River, Clarence River, N.S.W.

Brisbane, Ipswich, Qld.

Pultenaea densifolia, F.v.M.

A South Australian species, with very small, obovate concave leaves, with recurved tips, and flowers in axillary, sessile tufts, near the summit of the branches. Broad scarious bracts and bracteoles conceal the calyx, which is nearly three lines long, and has pungent-pointed lobes.

South Australia, Port Lincoln, Encounter Bay; doubtful from Victoria, "Murray Desert, F. Mueller."

Pultenaea Campbelli, Maiden and Betche.

A New South Wales species, near P. glabra, but with smaller and straighter leaves, and a slight pubescence on the small branches. It is easily distinguished from P. glabra, by its very small stipular bracteoles, fixed at the base of the calyx tube. These being all reddish brown, have the aspect of trifid bracteoles.

Walcha, N.S.W., J. F. Campbell, October, 1898.

Pultenaea aristata, Sieb.

A New South Wales species, with calyx and bracteoles like those of P. humilis, but its leaves are narrower, more concave, and are armed with a straight bristlet. The flowers are in dense terminal heads, unlike those of P. humilis, and are surrounded by reddish bifid bracts. The general aspect is that of P. plumosa.

Port Jackson, Appin, N.S.W.

Pultenaea plumosa, Sieb.

A species with narrow, concave leaves, without a bristle point. The broader leaved forms resemble P. humilis in foliage, and flower structure. The flowers are, however, in terminal heads, and the bracteoles are provided with broad stipules, are longer and broader, and are set under the calyx tube.

Port Jackson, Clarence River, Blackheath, N.S.W.

Pultenaea Bœuerleni, F.v.M.

A New South Wales species, near P. aristata, but with leaves filiform, channelled above, granular rough, and with no bristle point.

The petioles are conspicuous, and the stipules are long, appressed, and somewhat downy. Upper calyx lobes are much united, and and bracteoles are larger, oblong, mucronate, and fixed below the calyx tube.

Braidwood District, N.S.W., Bæuerlen.

Pultenaea elliptica, Smith.

A New South Wales species, with leaves elliptical to ovate, the upper ones being long-petiolate. Stipules broad, appressed, the upper ones being ciliate with long hairs. Flowers are crowded in upper axils like those of P. humilis, having bracteoles under the calyx, reddish, scarious with small point; var. thymifolia, Bth. has leaves smaller and narrower, and slightly smaller flowers.

Pultenaea rosea, F.v.M.

A species with terete leaves, and linear lanceolate bracteoles fixed under the calyx tube. It is, however, quite unique among its congeners in having pinkish or mauve-coloured flowers.

Summits of Grampians (Mt. William).

Pultenaea largiflorens, F.v.M.

A plant with obovate to linear-cuneate leaves, more or less concave or folded, and recurved at the ends, silky below, with flowers with a silky calyx with much falcate upper lobes, which give the buds a hooked aspect. Bracteoles are lanceolate to ovate, slightly hairy on the back, and are fixed well up on the calyx tube.

Grampians and North-Western District, Vic.

var. latifolia, n.v. To this may be referred the South Australian forms, which have much wider leaves, generally ovate-oblong, flat or slightly folded, and sometimes obcordate emarginate (Clare, S.A., Tate). In some of these, where the leaves are crowded, they appear almost ternate.

From Wedderburn, W. W. Watts, and from New South Wales, per W. Baker, comes a form differing from the normal only in having calyx, bracts and bracteoles larger, the last-named being fixed rather lower on the calyx tube, near its base. It is exactly similar in habit and general appearance to the Wimmera forms of P. largiflorens, and can scarcely rank as a variety.

EXPLANATION OF PLATES XIII., XIV., AND XV.

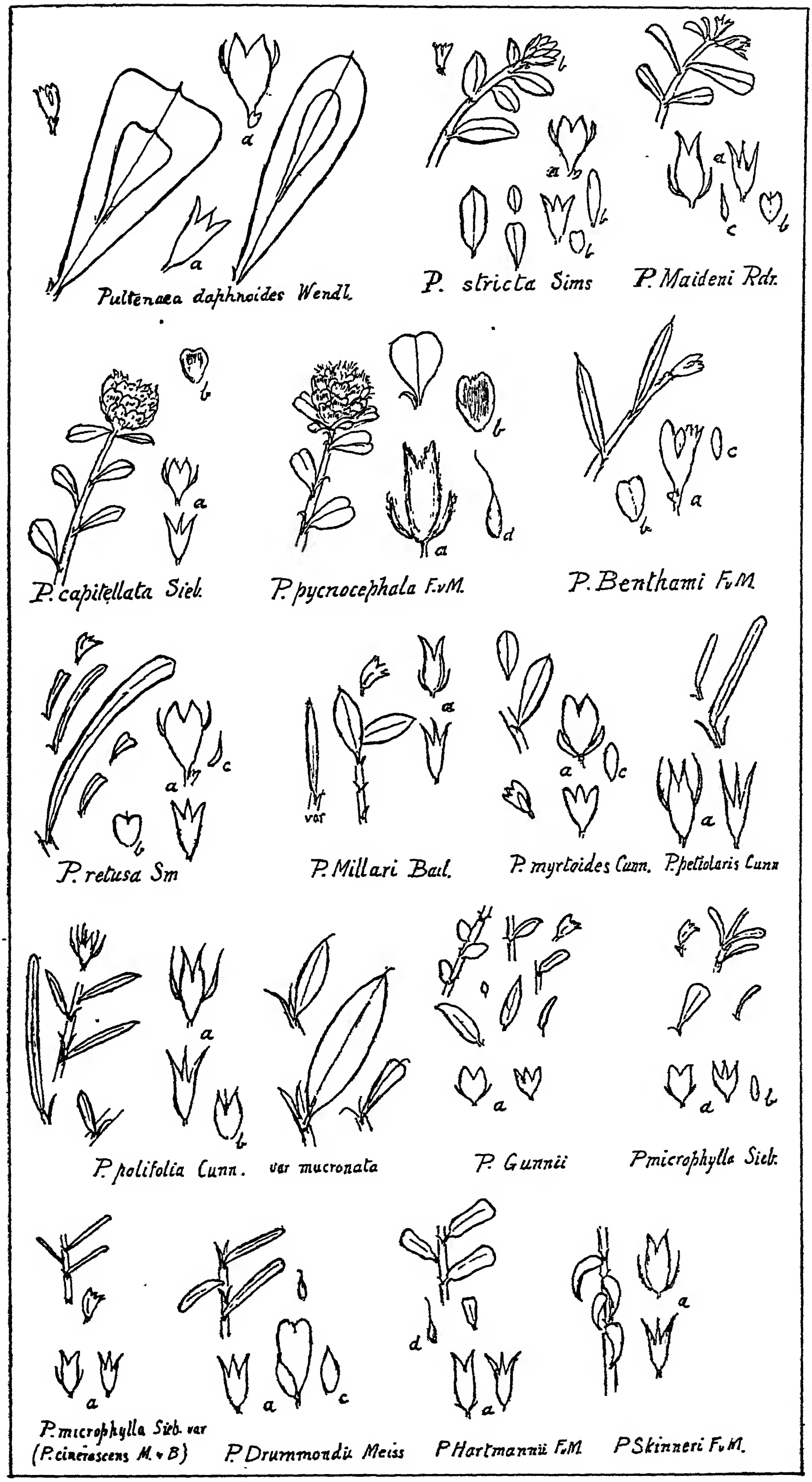
All drawings of leaves are natural size. Where the calyx is shown without reference letter it is natural size.

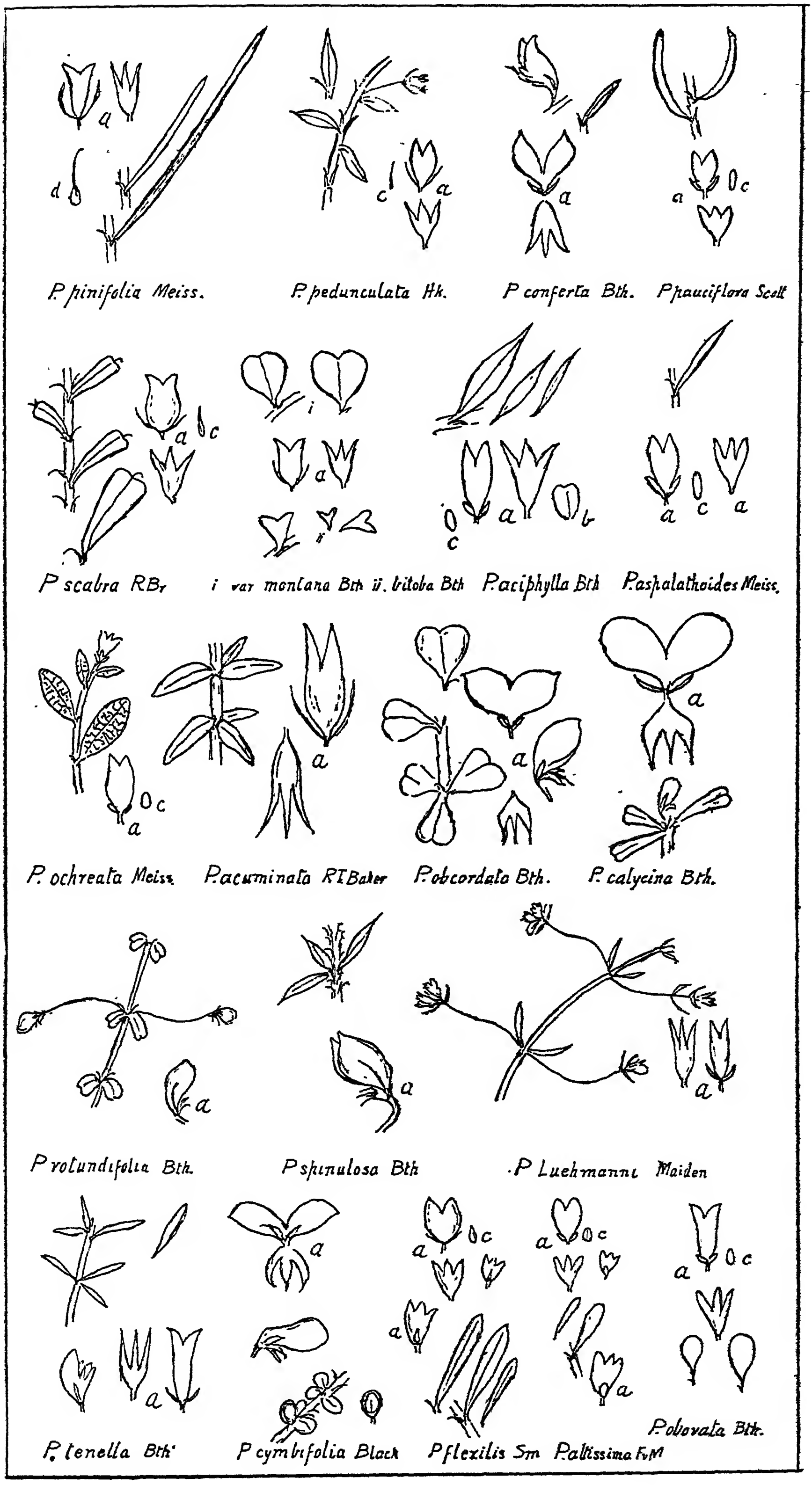
a Upper and lower calyx lobes × 2.

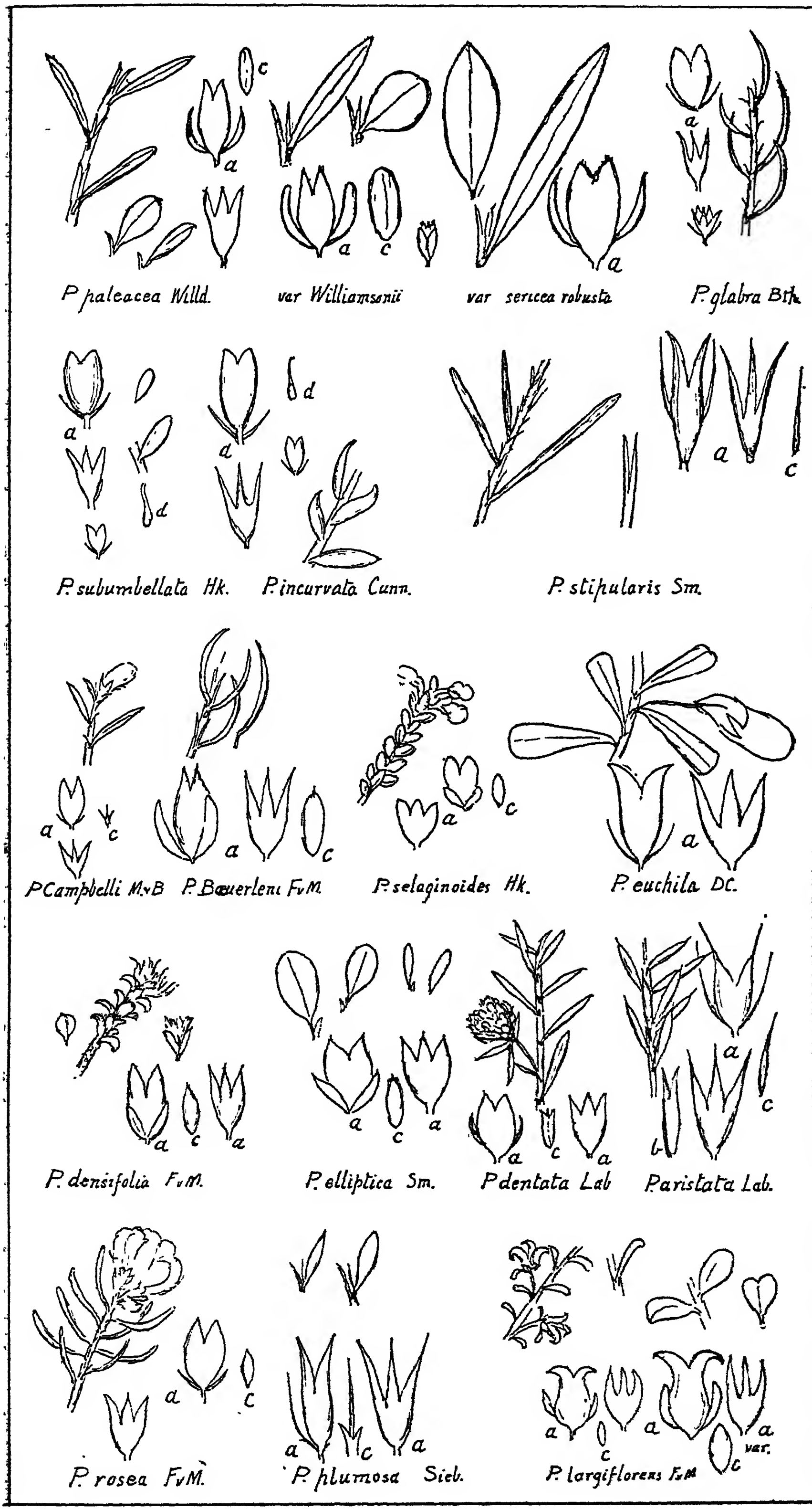
b Bract × 2.

c. Bracteole × 2.

d. Ovary and style × 2.


Pultenaea daphnoides Wendl.
P. stricta Sims
P. Maideni Rdr.
P. capitellata Sieb.
P. pycnocephala F.v.M.
P. Benthami F.v.M.
P. retusa Sm
P. Millari Bail.
P. myrtoides Cunn.
P. petiolaris Cunn.
P. polifolia Cunn.
var mucronata
P. Gunnii
P. microphylla Sieb.
P. microphylla Sieb. var (P. cinerascens M. & B.)
P. Drummondii Meiss
P. Hartmannii F.v.M.
P. Skinneri F.v.M.


P. pinifolia Meiss.
P. pedunculata Hk.
P conferta Bth.
P pauciflora Scott
P scabra RBr
i var montana Bth ii. biloba Bth
P. aciphylla Bth
P. aspalathoides Meiss.
P. ochreata Meiss.
P. acuminata RTBaker
P. obcordata Bth.
P. calycina Bth.
P rotundifolia Bth.
P spinulosa Bth
P Luehmanni Maiden
P. tenella Bth.
P cymbifolia Black
P flexilis Sm
P. altissima FvM
P. obovata Bth.


P paleacea Willd.
var Williamsonii
var sericea robusta
P. glabra Bth.
P. subumbellata Hk.
P. incurvata Cunn.
P. stipularis Sm.
P Campbelli M.v.B
P. Bæuerleni FvM.
P. selaginoides Hk.
P. euchila DC.
P. densifolia FvM.
P. elliptica Sm.
P dentata Lab
P. aristata Lab.
P. rosea FvM.
P. plumosa Sieb.
P. largiflorens FvM
var.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920.]

Art XVI.—*Notes on a Collection of Tertiary Fossils from Ooldea and Watson, South Australia.*

BY

FREDERICK CHAPMAN, A.L.S.
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Hon. Palaeont. Geol. Surv. Vict.

(With Plates XVI., XVII. and Text Figure.)

[Read 11th December, 1919.]

Introductory.

On account of the scarcity of information regarding fossils occurring in the area traversed by the construction of the Transcontinental Railway from Port Augusta to Kalgoorlie, it seems advisable to put on record some notes of the specimens now in the National Museum.

The fossils under consideration were collected by Messrs. F. A. Cudmore, R. C. Chandler and Dr. T. Griffith Taylor, B.E., B.A., F.G.S. Mr. Cudmore obtained a large collection of Miocene fossils, mainly as casts and moulds, in his recent trip to Ooldea and Watson, and a selection of these he has given to the Museum. I am also indebted to him for the photographs here reproduced, and for detailed information of the various fossiliferous exposures north and south of the railway.

Mr. R. C. Chandler was successful in obtaining a number of fossils in this locality during the early history of the line's construction, when engaged in acquiring natural history specimens for the Museum.

Dr. Griffith Taylor also collected a few fossils during his recent journey to Central South Australia, and has kindly donated the coral specimens—one of which is here figured—to the State collection.

Localities of Collection.

The Ooldea Soak[1] has been known to travellers from Fowler's Bay for many years. It is situated on the Nullaboor Plains, west of the sand-hill country, about 100 miles N.W. of Fowler's Bay, and about three miles north of the railway line. Various outcrops of

1. See S. A. White. The Emu, Jan. 1919, p. 189.

granite appear in this area, having a general north-westerly trend, and there are indications of the superimposed Tertiary beds having been displaced in that direction. This, indeed, may account for the occurrence of the Soak in this desert country, far away from any other visible water-hole, except some salt lakes, as Lake Tallacootra, to the south, and which are evidently due to a similar cause. It is just possible that sub-artesian water is tapped here, and remains held up by the heavier or impervious shell-marls of the Pleistocene deposit.

The collection made by Mr. Chandler comprises both Janjukian, or Miocene fossils (mainly as casts), and some Older Pleistocene material, cemented together or in loose specimens.

The small but interesting collection made by Dr. Griffith Taylor was from Janjukian beds. The specimens include a hard limestone with *Chlamys* cf. *murrayanus*, Tate sp., and two examples of a Janjukian coral, *Orbicella* (olim *Heliastraea*) *tasmaniensis*, Duncan sp., which had rarely before been found outside of Tasmania. This *Orbicella*, Mr. Cudmore informs me is abundantly scattered over various parts of the Plains.

The collection made by Mr. Cudmore comprises more than a hundred specimens. They are chiefly preserved in a hard ochreous and white limestone, generally as casts and moulds, although some still retain the shell structures, as *Chlamys murrayanus*. Mr. Cudmore's specimens came principally from the Ooldea Well (not used), 300 yards west and 200 yards south of Ooldea railway station, though a few of similar kinds were obtained from the half-mile cutting at Watson, next to Ooldea, on the road to West Australia. The limestone country is well shown by photographs here reproduced, taken by Mr. Cudmore.

On glancing at the geological map of this district, one sees that Ooldea is situated on the later Tertiary bed, but close to the boundary of outcrop of the Miocene series. From the disposition of the two Tertiary beds, as mapped, it would appear probable that the Pleistocene deposit represents a fairly shallow marine bed laid down upon, and flanking a Miocene limestone, which extended south-eastward as a promontory, as far as long. 133°30' at the present time, as now seen exposed in the elevated plains. From the fact that the Ooldea Soak is fresh, it is highly probable that the water is deep-seated, and has its origin in or below the mass of Miocene limestone, which must here be faulted, as seems to be indicated by the sporadic but linear arrangement of inliers of deep-seated rocks, and is not an ordinary soak in an impervious

bed. In fact, this theory of the presence of faults along this particular trend line is supported by the parallel system of fractures re-entrant along the coast, stepped in the same direction from the Head of the Bight to Anxious Bay, and even beyond.

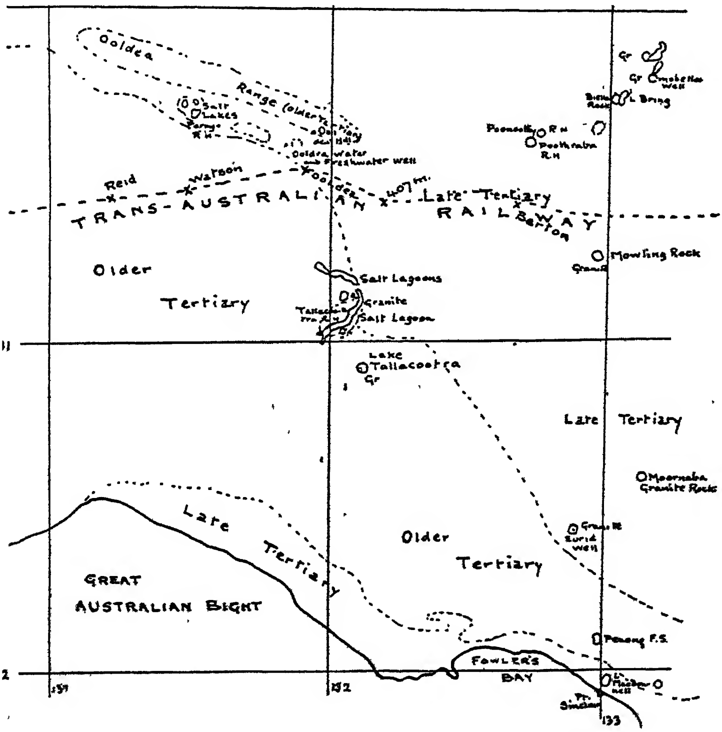

Fig. 1. Sketch Map of South Australian area including Fowler's Bay and the Ooldea Soak. Main details taken from the geological map of South Australia, by H. Y. L. Brown, 1899.

This shows the trend, in a north-westerly and south-easterly direction, of probable fracture zones, involving the Miocene and Pleistocene rocks. The direction of sand-ridges are also seen to be influenced by the underlying structure, since, as Mr. Henry Deane, M.A., informs me, they generally run in a similar way. These fracture lines would also appear to have a considerable bearing on the disposition of water holes, lagoons and soaks in this part of the country.

Areas in this map marked Granite may also include Metamorphic rocks, as Gneiss, Hornblende and Mica Schists; also Diabase dykes and mineral veins.

The Older Tertiary can be referred to the Miocene, to which the older fossiliferous beds of the Ooldea Soak belong.

The late Tertiary includes the Older Pleistocene of the Ooldea Soak and all subsequent stages, as Sand-dune rock and Concretionary limestone.

OLDER PLEISTOCENE FOSSILS FROM THE OOLDEA DISTRICT.

Order FORAMINIFERA.

Genus Orbitolites, Lamarck.

Orbitolites complanata, Lamarck.

Orbitolites complanata, Lamarck, 1801, Syst. Anim. sans Vert., p. 376. Carpenter, 1856, Phil. Trans., p. 224, pls. IV-IX. Chapman, 1913, Proc. R. Soc. Vict., vol. XXVI. N.S. pt. I. p. 170.

This species ranges from the Balcombian (Muddy Creek), through Janjukian (Mallee Bores) to Werrikooian and Pleistocene (Well borings, Murray Flats, and Croydon Bore, near Adelaide).

A fine sample of limestone, largely composed of the above fossil, together with mollusca (*Clanculus* and *Brachyodontes*) was presented to the National Museum by Mr. R. H. Matthews, who obtained it from Yorke Peninsula, six miles N.W. of Yorketown.

O. complanata occurred in the Croydon Bore as far down as 450 feet, and was there associated with *Laganum* and *Glycimeris*. At 395-415 feet the associated fauna was *Ostrea angasi*, *Glycimeris obliquus*, *G. convexus*, *Limopsis tenisoni* (recorded as *L. belcheri*), *Crassatellites oblonga*, *Mesalia provisi* and *Cassis fimbriatus*, This fauna contains some archaic forms, as *Mesalia provisi* and *Glycimeris convexus*, and the age of the deposit is certainly Werrikooian or Upper Pliocene. In the present sample, as in the raised beach at Yorke Peninsula, the beds are slightly younger, and may be referred to the older raised beach stage, or Lower Pleistocene.

Chandler Collection.

Class PELECYPODA.

Fam. ARCIDAE.

Genus Arca, Lamarck. Subgenus Anadara, Gray.

Arca (Andara) trapezia, Deshayes.

Arca trapezia, Deshayes, 1840, Mag. Zool., p. 21, 3 figs.

The shell attains a large size in this bed, and vies with similar large specimens in the Pleistocene of the West Melbourne Swamp. They reach a length of 104 mm., and a height of 81 mm.; the shells are embedded in a fine calcareous mud. Although the abundance of this species might suggest estuarine influence, the remainder of the associated mollusca are of the ordinary open water type.

Chandler Collection.

Fam. PINNIDAE.

Genus Pinna, Linné.

Pinna intermis, Tate.

Pinna zeylanica, Angas (non Gray), 1865, Proc. Zool. Soc., p. 655.

Pinna inermis, Tate, 1886, Trans. R. Soc. S. Austr., vol. IX., p. 71, pl. IV., Fig. 5.

Prof. Tate records this species from St. Vincent's Gulf, and generally from Eucla to the south-east coast of South Australia. It is found "partially buried vertically in mud or sand in a few fathoms water."

In some respects the fossil shell resembles the earlier portion of *P. virgata*, Menke, a West Australian living form, but is distinguished by the feeble radial ridges, which in the living species are very distinct.

Chandler Collection.

Fam. PECTINIDAE.

Genus Chlamys, Bolten.

Chlamys bifrons, Lamarck, sp.

Pecten bifrons, Lamarck, 1819, Anim. sans. Vert., vol. VI. pt. I., p. 164, No. 4.

Chlamys bifrons, Hedley, 1914, Biol. Results Endeavour, vol. II., p. 73.

This species is recorded from the shores of New South Wales, Victoria and South Australia. The related form, *Chlamys undulatus*, Sow. sp., is noted as living in Western Australia. The fossil specimens are typical of *C. bifrons*.

Chandler Collection.

Fam. MYTILIDAE.

Genus Brachyodontes, Swainson.

Brachyodontes hirsutus, Lamarck, sp.

Mytilus hirsutus, Lamarck, 1818, Anim, sans Vert., vol. VI. pt. I. p. 120, No. 5.

Brachyodontes hirsutus, Lam. sp., Hedley, 1917, Journ. R. Soc. New South Wales, vol. LI. Suppl. p. 11.

This species is abundant on the South Australian, Victorian and New South Wales coasts, but seems to be unrecorded from Western Australia.

Chandler Collection.

Fam. VENERIDAE.

Genus **Marcia,** H. and A. Adams. Subgenus **Katelysia,** Römer

Marcia (Katelysia) strigosa, Lamarck, sp.

Venus strigosa, Lamarck, 1818, Anim. sans Vert., vol. V., p. 605.

This common shell is found on muddy and sandy beaches at low tide.

Chandler Collection.

Class GASTEROPODA.

Fam. TROCHIDAE.

Genus **Clanculus,** Montfort.

Clanculus dunkeri, Koch sp.

Trochus dunkeri, Koch, 1843, in Philippi, Abbild, und Beschr. neuer Conch., vol. 1, pt. III. p. 67, pl. II. Fig. 5.

Clanculus dunkeri, Koch sp., Pritchard and Gatliff, 1902, Proc. R. Soc., Vict. vol. XIV. (N.S.), pt. II., p. 121.

This species is found living in South Australia and Western Australia, and is recorded from Westernport, Victoria.

Chandler Collection.

Fam. TURRITELLIDAE.

Genus **Turritella,** Lamarck.

Turritella clathrata, Kiener.

Turritella clathrata, Kiener, 1843, Icon. Coq. Viv., p. 33, pl. XIV., Fig. 1, Reeve, 1849, Conch, Icon., vol. V., pl. VIII., Fig. 37. Pritchard and Gatliff, 1900, Proc. R. Soc. Vict. vol. XII. (N.S.) pt. II., p. 202.

This is a well known South Australian species, and is also recorded from the south-west coast of Victoria.

Chandler Collection.

Fam. CERITHIIDAE.

Genus **Bittium,** Leach.

Bittium cerithium, Quoy and Gaimard sp.

Turritella cerithium, Quoy and Gaimard, 1834, Voyage Astrolabe, vol. III. p. 139, pl. LV. Figs. 27, 28.

A common form in Victorian waters; apparently absent from lists of other States.

Chandler Collection.

Fam. COLUMBELLIDAE.

Genus **Columbella**, Lamarck.

Columbella aff. semiconvexa, Lamarck sp.

Buccinum semiconvexa, Lamarck, 1822, Anim. sans Vert., vol. VII. p. 272.

Pyrene semiconvexa, Lam. sp., Hedley, 1917, Journ. R. Soc. New South Wales, vol. LI. Supp. p. 90.

This is a common shell, frequent in most shallow sands round the Southern Australian coasts.

Chandler Collection.

Fam. FUSIDAE.

Genus **Fusus**, Lamarck.

Fusus australis, Quoy and Gaimard.

Fusus australis, Quoy and Gaimard, 1833, Voy. Astrolabe, vol. II. p. 495, pl. XXXIV. Figs. 9-14. Tryon, 1881, Man. Conch. vol. III., p. 55, pl. XXXIV., Figs. 113, 116, 118.

A common shore-living shell in South Australia and Victoria.

Chandler Collection.

Genus **Fasciolaria**, Lamarck.

Fasciolaria australasia, Perry sp.

Pyrula australasia, Perry, 1811, Conchology, pl. LIV., Fig. 4.

Fasciolaria australasia, Perry sp., Hedley, 1903, Mem. Austr. Mus., vol. IV., p. 373.

A well-known south coastal species. Recorded from the Western Bight in 100 fathoms; the species also ranges to shallower depths.

Chandler Collection.

Fam. VOLUTIDAE.

Genus **Mitra**, Lamarck.

Mitra pica, Reeve.

Mitra pica, Reeve, 1845, Proc. Zool. Soc. Lond., p. 49, Idem, 1845, Conch. Icon., vol. II., pl. XXXI. Fig. 247. Pritchard and Gatliff, 1899, Proc. R. Soc. Vict., vol. XI. (N.S.) pt. II. p. 188.

This species is found living in South Australia, and it also occurs along the Victorian coast from Westernport to Warrnambool.

Chandler Collection.

Fam. BULLARIIDAE.

Genus **Bullaria**, Rafinesque.

Bullaria botanica (Hedley).

Bulla australis, Gray, 1825, Annals of Phil., N.S. vol. XXV. p. 408.

Bullaria botanica, Hedley, 1918, Journ. R. Soc. N. S. Wales, vol. LI. Suppl. p. 104 (nom. mut. for *B. australis*, Gray non Ferussac).

A well distributed species in littoral waters round the southern parts of Australia.

Chandler Collection.

MIOCENE FOSSILS FROM THE OOLDEA DISTRICT.

Order FORAMINIFERA.

Orbitolites complanata, Lamarck.

Genus **Orbitolites**, Lamarck.

This discoidal foraminifer, here also recorded from the Older Pleistocene (see antea page 228) reaches a diameter of $1\frac{1}{2}$ inches. The present occurrence of this large variety is interesting, since the older, Oligocene form in Australia is much smaller, and the younger, early and late Pleistocene, specimens are not quite so large. It is fairly common here.

Cudmore Collection.

Class ANTHOZOA.

Fam. TURBINOLIIDAE.

Genus **Placotrochus**, Edwards and Haime.

Placotrochus deltoideus, Duncan.

Placotrochus deltoideus, Duncan, 1864, Ann, and Mag. Nat. Hist. vol. XIV., p. 164, pl. V. Fig. 5.

Casts only. Cudmore Collection.

Fam. STYLOPHORIDAE.

Genus **Stylophora**, Schweigg.

Stylophora sp. nov.?

Numerous moulds and casts of a branching form. Cudmore Collection.

Fam. ASTRAEIDAE.

Genus **Montlivaltia,** Lamaroux.

cf. *Montlivaltia*, sp.

A species with a large discoidal, depressed calyx.

Cudmore Collection.

Genus **Orbicella,** Dana.

Orbicella tasmaniensis, Duncan sp. Plate I. Fig. 1.

Heliastraea tasmaniensis, Duncan, 1876, Quart. Journ. Geol. Soc. vol. XXXII. p. 342, pl. XXII., Figs. 1-3.

Astrangia tabulosa, Tate, 1893, Journ. R. Soc. N. S. Wales, vol. XXVII. p. 145, pl. XIII. Fig. 2.

Two species of the above named coral were presented by Dr. Griffith Taylor. They occur in the hard, reddish limestone of the Tertiary series, and were found on the surface of a salt lake east of Ooldea. One of them is preserved in hard, semi-crystalline limestone, in which the coral structure is much obscured; whilst the other is weathered and whitened, so that it has the appearance of a living coral. The structure of the weathered specimen is, however, none the less perfect, for this process has simply picked out the calcareous infilling. A large number of wind-worn pieces of this coral was also secured by Mr. Cudmore, who states that they occur scattered over the limestone plains. By their blackened and polished surfaces the fragments appear to have been exposed to the weather for a long time.

The species, living and fossil, formerly referred to the genus *Heliastraea*, are now relegated to *Orbicella* by Verrill and Quelch[2] by reason of priority.

There is a close agreement of these specimens from Ooldea with those from Tasmania, though the former have the calices rather larger in diameter (9 :8). The weathered specimen shows that, although the dissepiments are, as a rule, curved downwards, this is by no means invariable. This specimen has the mesenteric pouches filled with a pale glauconite, thus showing, in common with other organic marine bodies, a tendency for the body cavity to act as a receptacle for the deposition of the hydrous silicate of iron, alumina and potash to form that mineral.

Orbicella tasmaniensis has, up to the present, been unknown from any locality outside Tasmania, excepting Flemington, Victoria.

Taylor and Cudmore Collections.

2. Rep. Chall., Vol. XVI., Zool. 1886, p. 106.

Class ECHINOIDEA.

Fam. CLYPEASTRIDAE.

Genus **Laganum**, Gray.

?Laganum sp.

A fragmentary test shows a portion of the sub-angulately contoured ambitus and internal supporting pillars. The genus was previously recorded by Tate from the Tertiary of St. Vincent Gulf, South Australia. (*L. platymodes.*)

Cudmore Collection.

Class PELECYPODA.

Fam. PARALLELODONTIDAE.

Genus **Cucullaea**, Lamarck.

Cucullaea corioensis, McCoy.

Cucullaea corioensis, McCoy, 1876, Prod. Pal. Vict. Dec. III. p. 32, pl. XXVII. Figs. 3-5*b*. Tate, 1886, Trans. R.S.S. Austr., vol. VIII. p. 144. Harris, 1897, Cat. Tert. Moll. pt. I. Australasia. (Brit. Mus.) p. 336.

Numerous casts of this widely ranging species (Oligocene to Werrikooian), occur here.

Cudmore Collection.

Fam. ARCIDAE.

Genus **Glycimeris**, Da Costa.

Glycimeris maccoyi, Johnston sp.

Pectunculus laticostatus, McCoy non Quoy and Gaimard, 1875, Prod. Pal. Vict. Dec. II. p. 26, pl. XIX. Figs. 10-14.

Pectunculus maccoyi, Johnson, 1884, Papers and Proc. R. Soc. Tas., p. 199, Id., 1888, Geol. Tas, p. 225, pl. XXX. Fgs, 1, 1*d*.

Casts and moulds of this common Tertiary species occur in the hard limestone.

Cudmore Collection.

Fam. PECTINIDAE.

Genus **Chlamys**, Bolten.

Chlamys murrayanus, Tate sp.

Pecten murrayanus, Tate, 1886, Trans. Roy. Soc. S. Australia, vol. VIII., p. 105, Pl. VII., Figs. 5, *a*, *b*.

One of the specimens found four miles west of Ooldea by Dr. Griffith Taylor, is a cast in hard cream coloured limestone. Others collected from near the same locality (Watson cutting), by Mr. Cudmore, show a denuded shell, the riblets being devoid of ornament except in one case, where the structure is seen to be that of *C. murrayanus;* the appearance is misleading, and the shell might easily be mistaken for one of the Amusium type, like *A. yahliensis*, T. Woods sp.

In the Miocene seas *C. murrayanus* attained a large size, some examples measuring as much as 3½ inches in length.

Previously recorded from South Australia in Miocene beds of the Lower Murray River.

Taylor, Chandler and Cudmore Collections.

Chlamys aldingensis, Tate sp.

Pecten aldingensis, Tate, 1886, Trans. R.S.S. Austr., vol. VIII., p. 109, pl. VII., Figs. 1*a-c*. Chapman, 1912, Mem. Nat. Mus. Melbourne, No. 4, p. 48.

Previously recorded from South Australia in the Miocene glauconitic limestone of Aldinga Bay. Dennant notes it from Stansbury, South Australia, and the present writer from the polyzoal limestone of Seal River, King Island. Cudmore Collection.

Fam. SPONDYLIDAE.

Genus **Spondylus**, Linné.

Spondylus cf. *gaederopoides*, McCoy.

Spondylus gaderopoides, McCoy, 1876, Prod. Pal. Vict., Dec. IV. p. 27, pl. XXXVIII. Figs. 1-1*d*.

Spondylus gaederopoides, McCoy, Tate, 1886, Trans. R. Soc. S. Austr., vol. VIII. p. 121.

Two casts of united valves occur here. They are solidly built, and of the general form of the above species, which, by the way, is a restricted Miocene fossil. Cudmore Collection.

Fam. LIMIDAE.

Genus **Lima**, Bruguière. Subgenus **Limatula**, Wood.

Lima (Limatula) jeffreysiana, Tate.

Lima (Limatula) jeffreysiana, Tate, 1886, Trans. R.S.S. Austr. vol. VIII. p. 119, pl. IV., Fig. 8.

A well preserved shell is found here. Cudmore Collection.

Fam. CRASSATELLITIDAE.

Genus **Crassatellites**, Kruger.

Crassatellites cf. *oblonga*, T. Woods sp.

Crassatella oblonga, T. Woods, 1875, Papers and Proc. R. Soc. Tasmania (1876), p. 25, pl. II., Fig. 11.

This internal cast closely resembles the Table Cape form specified above, especially in the anterior position of the umbones.

Cudmore Collection.

Fam. CARDITIDAE.

Genus **Cardita**, Bruguière.

Cardita cf. *tasmanica*. Tate.

Cardita tasmanica, Tate, 1886, Trans. R. Soc. South Austr. vol. VIII. p. 154, pl. XII. Fig. 13.

The species appears to be represented here by an internal cast, judging by the shape and number of riblets, with impressions of some still preserved, it is in all probability referable to the above

Cudmore Collection.

Cardita scabrosa, Tate.

Cardita scabrosa, Tate, 1886, Trans. R. Soc. South Australia, vol. VIII., p. 152, pl. II., Fig. 4.

A good internal mould of this species occurs here.

Cudmore Collection.

Fam. LUCINIDAE.

Genus **Lucina**, Bruguière.

Lucina planatella, Tate, 1886, Trans. R. Soc. S. Austr., vol. VIII., pl. XII. Fig. 11, Idem, 1887, ibid, vol. IX. p. 146.

Both moulds and casts, showing ornament and internal form are found in some frequency. The species was originally described as a Table Cape fossil. I have since identified it amongst fossils from Maude.

Cudmore Collection.

Fam. CARDIIDAE.

Genus **Cardium** Linné.

Cardium victoriae, Tate.

Cardium victoriae, Tate, 1887, Trans. R. Soc. S. Austr. vol. IX. p. 151, pl. XIV. Figs. 1*a*, *b*. Harris, 1897, Cat. Tert. Moll. Australasia (Brit. Mus.), p. 367.

Several examples showing typical surface ornament are found here.

Cudmore Collection.

Subgenus **Protocardium**, Beyrich.

Cardium (Protocardium) antisemigranulatum, McCoy.

Cardium (Protocardium) antisemigranulatum, McCoy, 1877, Prod. Pal. Vict., Dec. V. p. 16, pl. XLIV. Figs. 2, 3.

Represented here by an internal cast.

Cudmore Collection.

Fam. VENERIDAE.

Genus **Venus**. Subgenus **Chione**, Megerle.

Venus (Chione) cainozoicus, T. Woods sp.

Venus (Chione) cainozoica, T. Woods, 1877, Papers and Proc. R. Soc. Tas. for 1876, p. 113.

Chione cainozoicus, T. Woods sp., Tate, 1887, Trans. R. Soc. S. Austr. vol. IX. p. 156, pl. XVI. Figs. 3*a*, *b*.

Two examples. Cudmore Collection.

Venus (Chione) ? hormophora, Tate, sp.

Chione hormophora, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX., p. 155, pl. XV. Figs. 1*a*, *b*.

A cast and also an impressed mould of the shell was found. The former shows the straight ventral region, and the latter the ornamentation, of the above typical Table Cape species.

Cudmore Collection.

Genus **Dosinea**, Scopoli.

Dosinea johnstoni, Tate.

Dosinea johnstoni, Tate, 1887, Trans. R. Soc. S. Aust., vol. IX. p. 161, pl. XIV. Figs. 9 and 12.

A mould of a shell of a *Dosinea* in white limestone shows by a wax squeeze the characteristic costation of the above species. The concentric ridges measure 20 in a breadth of 10 mm. and are elevated rather than depressed and rolled over to become almost confluent, as in *D. densilineata*, Pritchard.[3] The length of the present example, if complete, would measure about 50 mm. *D. johnstoni* has a long vertical range, from Balcombian to Kalimnan (Balcombe Bay, Table Cape, Upper Muddy Creek).

Chandler and Cudmore Collections.

3. Proc. Roy. Soc. Vict., Vol. VIII., 1896, p. 135, pl. IV., Figs, 5-7.

Fam. TELLINIDAE,

Genus **Tellina**, Linné.

Tellina, aff. *albinelloides*, Tate.

Tellina albinelloides, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. p. 164, pl. XVI. Figs. 4*a*, *b*.

A large shell-impression was found here, which agrees in the main characters with the above species. *T. albinelloides* is a Kalimnan form, so that this occurrence, if it be correctly assigned, is unique as a Miocene fossil.

Cudmore Collection.

Tellina, cf. *cainozoica*, T. Woods.

Tellina cainozoica, T. Woods, 1877, Papers and Proc. R. Soc. Tas. for 1876, p. 113. Tate, 1887, Trans. R. Soc. S. Austr., vol. IX., p. 164, pl. XVIII. Fig. 5.

A solitary specimen, doubtfully referred to the above species occurs here.

Cudmore Collection.

Fam. CORBULIDAE.

Genus **Corbula**, Lamarck.

Corbula pyxidata.

Corbula pyxidata, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. 117, pl. XVII. Figs, 12*a*, *b*.

A well defined cast in white limestone occurs here.

Cudmore Collection.

Corbula ephamilla, Tate.

Corbula ephamilla, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. p. 176, pl. XVII., Figs. 13*a*, *b*. 14.

A mould of this widely distributed species was found here.

Cudmore Collection.

Fam. TEREDINIDAE.

Genus **Teredo**, Linné.

Teredo directa, Hutton, sp.

Cladopoda directa, Hutton, 1877, Trans. N.Z. Inst., vol. IX. p. 597, pl. XVI. Fig. 13.

Teredo directa, Hutton, sp., Suter, 1914, Rev. Tert. Moll. N. Zealand, pt. I. (Pal. Bull, 2, N.Z. Geol. Surv.), p. 54.

Two casts of Teredo tubes found here correspond with the almost straight small tubes of the above species which came from the Miocene of Canterbury, N. Zealand.

Cudmore Collection.

Class GASTEROPODA.

Fam. TROCHIDAE.

Genus Astele, Lwainson.

Astele sp.

Several casts and moulds of a form referable to the above genus occur in the white limestone. It has rather smooth, flat whorls, and a thread-like ornament round the base. It resembles an undescribed species from the Miocene of Victoria.

Cudmore Collection.

Fam. NATICIDAE.

Genus Natica, Scopoli.

Natica substolida, Tate, var. *grandis, nov.*

Description.—Shell of the type of *Natica substolida*, Tate,[4] but of much larger dimensions and heavier build, the length being more than twice that of the specific form (54 mm., as compared with 25 mm. in the species).

A large specimen of *Natica*, somewhat deformed, but evidently belonging to the new variety, has been figured by Mr. C. J. Gabriel and the writer from the Mallee Bores, under the name of *N. subinfundibulum*, var. *crassa*, Tate.[5]

This large variety is fairly common in the limestone of the Ooldea district, and its large size (over 2 inches in length), makes it a conspicuous fossil.

Cudmore Collection.

Natica cf. *hamiltonensis*, Tate.

Natica hamiltonensis, Tate, 1893, Trans. R. Soc. S. Austr., vol. XVIII. pt. 2, p. 319, pl. X. Fig. 6.

A cast referred with slight doubt to this common Tertiary fossil was found here.

Cudmore Collection.

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4. *Natica (Neverita) substolida*, Trans. R. Soc. S. Austr., Vol. XVII., p. II, 1893, p. 323, pl. VI. Fig. 3.
5. Proc. Roy. Soc. Vict., Vol. XXVI. (N.S.) pt. II., 1914, p. 321, pl. XXV., Figs, 15*a*, *b*,

Genus **Euspira**, Agassiz.

Euspira cf. *effusa*, Tate sp.

Ampullina effusa, Tate, 1893, Trans. R. Soc. S. Austr., vol. XVII. pt. 2, p. 327, pl. X. Figs. 2, 2*a*.

A cast of a globosely whorled naticoid shell was found, of which there is very little doubt as to its relationship. *E. effusa* was recorded by Tate from the Miocene glauconite sands of the Adelaide Bore, whilst Dennant notes it from Brown's and Hamilton Creeks, in Victoria, in beds of Miocene age.

Cudmore Collection.

Fam. CERITHIIDAE.

Genus **Cerithium**, Bruguière.

Cerithium pritchardi, Harris.

Potamides semicostatum, Tate (non Deshayes), 1885, Papers and Proc. R. Soc. Tas. for 1884, p. 226.

Cerithium pritchardi, Harris, 1897, Cat. Tert. Moll. Australasia (Brit. Mus.) p. 225, pl. VII. Fig. 3.

Numerous pieces of this strongly built shell are included in the collection, some of which had been weathered. They were found accompanied by *Orbicella* in the exposed rubble of the plains. It is a restricted Miocene fossil.

Cudmore Collection.

Genus **Newtoniella**, Cossman.

Newtoniella sp.

A hollow mould of a shell referable to this genus, and probably new, occurs here.

Cudmore Collection.

Fam. CYPRAEDIAE.

Genus **Cypraea**, Linné.

Cypraea spp.

These are casts, fairly common, related to the typical forms *C. subsidua*, Tate, and *C. murraviana*, Tate.

Cudmore Collection.

Fam. VOLUTIDAE.

Genus, Lyria, Gray.

Lyria acuticostata, sp. nov.

Description.—Shell long-ovate, volutiform; apically pointed, anteriorly truncated; whorls moderately high, entirely costate, the acute riblets numbering about 18 on the body whorl. Protoconch small, as compared with *L. semiacuticostata*, Prichard,[1] and consisting of two volutions.

The above description is completed from an example in the Dennant collection, from Bird Rock, Torquay, Victoria.

Dimensions.—The limestone specimen measured when complete, circ. 60 mm.; the Torquay marl specimen, 42 mm.

Comparison.—In general shape and acute apex this species is related to *L. semiacuticostate* from Table Cape, but differs essentially in having continuous costation. It is clearly an ancestor of the living *Lyria mitraeformis*,[2] from which it differs in the more numerous costae and slightly narrower shell.

Cudmore Collection.

Genus Voluta, Linné.

Voluta validicostata, Tate.

Voluta alticostata, Tate, 1889, Trans. R. Soc. S. Austr., vol. XI. p. 122, pl. V. Fig. 7.

Voluta validicostata, Tate (nom. mut.), vide Dennant and Kitson, Cat. Cain. Foss., 1903, p. 100.

Several casts of young and median grown shells are found here. Although occurring in the Balcombian, in Victoria, it is more typical of Janjukian strata, both there and in South Australia.

Cudmore Collection.

Voluta cf. *ancilloides*, Tate.

Voluta ancilloides, Tate, 1889, Trans. R. Soc., S. Austr., vol. XI. p. 126, pl. III., Fig. 7.

A cast of a shell of the above specific type occurs in the hard limestone from Ooldea. *V. ancilloides* is a well-known Table Cape fossil.

Chandler Collection.

Fam. OLIVIDAE.

Genus **Ancilla**, Lamarck.

Ancilla sp.

A cast of a shell occurs in the limestone, of the type of an *Ancilla* found at Spring Creek and Table Cape (Nat. Mus. Coll.), but of very large dimensions. It must have attained a length of about 50 mm. when complete, whereas the Spring Creek specimens rarely measure more than 20 mm., a difference accounted for by the variation in sedimentation.

Fam. TURRITIDAE.

Genus **Clavatula**, Lamarck.

? *Clavatula* sp.

This is an internal cast of the apical portion of a large conical species, with the earlier whorls faintly costate and medially ridged.

Cudmore Collection.

Fam. CONIDAE.

Genus **Conus**, Linné.

Conus spp.

Probably several species are represented here, but they are all internal casts. So far as can be seen, the commonest form is related to *Conus ligatus*, Tate.[6]

Chandler and Cudmore Collections.

Class CEPHALOPODA.

Fam. NAUTILIDAE.

Genus, **Nautilus**, Linné.

Nautilus sp. cf. *geelongensis*, Foord.

Nautilus geelongensis, Foord, 1891, Cat. Foss. Cephalopoda (Brit. Mus. pt. II. p. 332, woodcut, Fig. 69. Chapman, 1915, Proc. R. Soc. Vict. vol. XXVII (N.S.), pt. II. p. 354, pl. IV. Figs. 7-9).

The present example is a large specimen (a fragmentary cast), having an approximate diameter of about 6 inches when com-

6. Trans. Roy Soc. S. Austr., Vol. XIII., pt. 2, 1890, p. 196, pl. VII. Figs. 4, 4a, b; pl. VIII., Fig. 9.

plete. In its broad contour it is nearest to *N. geelongensis*, a Janjukian species from the polyzoal rock generally.

Cudmore Collection.

FOSSIL LISTS.—OOLDEA DISTRICT.

Older Pleistocene.

Orbitolites complanata, Lam.
Arca (Anadara) trapezia, Desh.
Pinna inermis, Tate.
Chlamys bifrons, Lam. sp.
Brachyodontes hirsutus, Lam. s.p.
Marcia (Katelysia) strigosa, Lam. sp.
Clanculus dunkeri, Koch sp.
Turritella clathrata, Kiener.
Bittium cerithium, Q. and G. sp.
Columbella aff. *semiconvexa*, Lam. sp.
Fusus australis, Q. and G.
Fasciolaria australasia, Perry sp.
Mitra pica, Reeve.
Bullaria botanica, Hedley.

Miocene.

Orbitolites complanata, Lam.
Placotrochus deltoideus, Dunc.
Stylophora, sp. nov.
cf. *Montlivaltia*, sp.
Orbicella tasmaniensis, Dunc. sp.
?*Laganum* sp.
Cucullaea corioensis, McCoy.
Glycimeris maccoyi, Johnst. sp.
Chlamys murrayanus, Tate, sp.
Chlamys aldingensis, Tate sp.
Spondylus cf. *gaederopoides*, McCoy.
Lima (Limatula) jeffreysiana, Tate.
Crassatellites cf. *oblonga*, T. Woods sp.
Cardita cf. *tasmanica*, Tate.
Cardita scabrosa, Tate.
Lucina planatella, Tate.
Cardium victoriae, Tate.
Cardium (Protocardium) antisemigranulatum, McCoy.
Venus (Chione) cainozoicus, T. Woods sp.
Venus (Chione) ?*hormophora*, Tate.
Dosinea johnstoni, Tate.
Tellina aff. *albinelloides*, Tate.
Tellina cf. *cainozoica*, T. Woods.
Corbula pyxidata, Tate.
Corbula ephamilla, Tate.
Teredo directa, Hutton sp.
Astele sp.
Natica substolida, Tate, var. *grandis*, nov.
Natica cf. *hamiltonensis*, Tate.
Euspira cf. *effusa*, Tate sp.
Cerithium pritchardi, Harris.
Newtoniella sp.
Cypraea spp.
Lyria acuticostata, sp. nov.
Voluta validicostata, Tate.
Voluta cf. *ancilloides*, Tate.
Ancilla sp.
Clavatula sp.
Conus spp.
Nautilus geelongensis, Foord.

Episodes in the Formation of the Beds of the Great Bight Area.

In pre-Miocene times the area abutting on the Cretaceous of the Lake Eyre district to the north-west, to Charlotte Waters on the north, to Albany, on the west, and to the Adelaide Plains on the east, and far to the south on what is now the Southern Ocean, was probably dominated by an estuarine or generally base-levelled country. This area also extended through the Riverina as far as Wagga, in New South Wales, and occupied a large part of the Wimmera and Mallee districts of Victoria. The underlying (fundamental) rocks of this area consist mainly of granite,[7] chloritic slate, felspathic quartzites, slaty rocks and sandstones, all excepting the granite possibly referable either to the Ordovician, Cambrian or metamorphic series, including Algonkian. The deposits laid down on these basal rocks were river, estuarine, swamp and lake accumulations, consisting of sands and clays with carbonaceous and lignitic material.

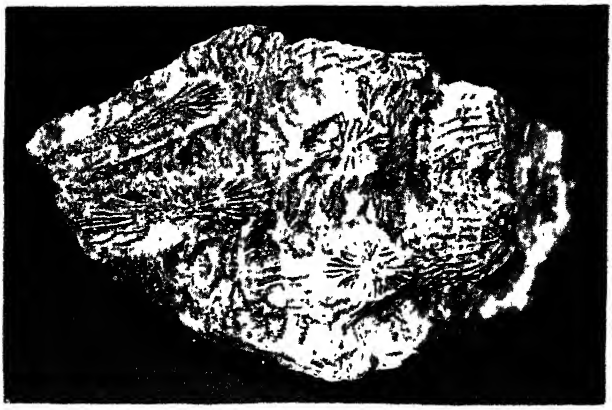
Following the deposition of these beds, which, by the way, were not uniformly spread over the entire area mentioned, there were occasional oscillations which brought them below sea-level, causing an interstratification of marine beds with the terrestrial. Later, the oscillations ended in a steady to quick downward movement until a depth of at least 100 fathoms below sea-level was reached. In this sea-bed a rich deposit of calcareous mud was formed, filled with debris of polyzoa, echinoids, mollusca and foraminifera. These beds can be referred to the Janjukian series of Victoria, and are homotaxial with the Miocene of Europe.

In Lower Pliocene times (Kalimnan series) the sea-bed rose to within a few fathoms of the surface, with fine sandy deposits, upon which flourished molluscs as *Ostrea*, *Natica*, *Turritella* and the sea-urchin, *Laganum*, amongst many other organisms. In places there were huge oyster banks, and in the more rocky parts vast deposits of mollusca peculiar to such conditions, as *Mytilus*, *Barnea*, *Venerupis*, *Arca*, *Cucullaea* and *Glycimeris*, a few species of which facies are still living. Possibly a part of the Miocene limestone of which the fauna is here discussed, may have persisted into the Lower Pliocene, as evidently a few forms, such as *Tellina* cf. *albinelloides* and *Laganum*, seem to indicate.

In the later period of the Pliocene this sea-bed again deepened, and a shell deposit with many existing species was laid down.

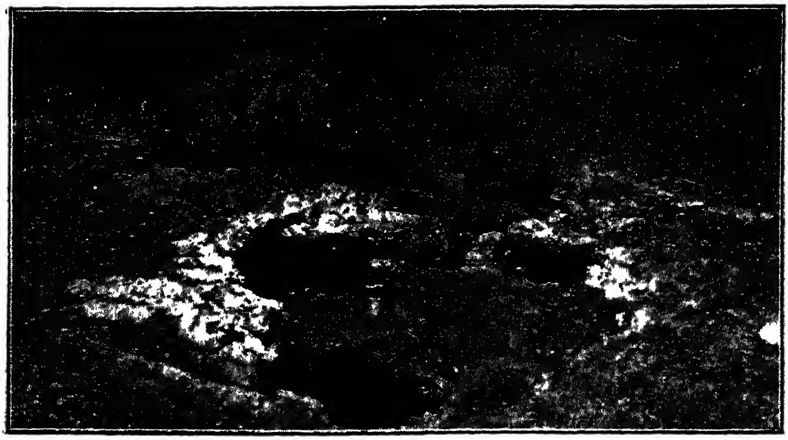
7. In the Albany district these older limestones=Plantagenet Beds) have been shown by J. T. Jutson and E. S. Simpson (Journ. and Proc. Roy. Soc. W. Australia, Vol. II., 1917, p. 48) to have been laid down on the granite.

1



2

Fossils of Ooldea



Tertiary Limestone Plains near Ooldea

This deposit can be referred to the Werrikooian, as it is geologically comparable with the Glenelg upraised marine beds. It also occurs in the upper part of the Croydon Bore, near Adelaide, to about 400 feet. One of the commonest fossils in this bed is *Orbitolites complanata.* This foraminifer is now living on the Australian coast, but at lower latitudes. For example, on the west coast, at Shark's Bay (lat. 25°S.), and on the east coast at the Barrier Reef (from about lat. 23°S.). The occurrence of *Orbitolites* at the higher latitude of 32°S. denotes a warmer climate in Werrikooian and Older Pleistocene times. During the Weerikooian a number of the molluscan species became extinct, whilst others, along with *Orbitolites*, persisted.

In the next period, the Older Pleistocene, the bed of shells and foraminifera emerged from the sea, and was raised to a height of about 381 feet between that time and the present; it is found to-day overlying the Janjukian limestones at the Ooldea Soak, 100 miles inland. Upon the present coast line, in late Pleistocene times there was laid down an ordinary beach deposit with shells, and this is now found forming ledges and raised beaches at protected places along the southern coast, denoting the continuance of the uplift along the shores of the Great Bight even to the present time.

EXPLANATION OF PLATES.

Plate XVI.

Fig. 1.—*Orbicella tasmaniensis*, Duncan sp. Miocene (Janjukian), From surface of Salt Lake, W. of Ooldea, South Australia. Circ. nat. size.

,, 2.—Fragment of Raised Beach, of Older Pleistocene age; showing *Pinna inermis*, Tate (shell at base), *Bullaria botanica*, Hedley, and *Bittium cerithium*, Q. and G. sp. Ooldea district, South Australia. Three-fifths nat. size.

Plate XVII.

Fig. 1.—Cutting with fossiliferous Tertiary limestone (Miocene); half mile east of Watson.

,, 2.—Blowhole in Miocene limestone, near Ooldea. (Photographs on this plate by Mr. F. A. Cudmore.)

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XVII.—*The Longevity of Cut Flowers.*

By ELLINOR ARCHER, M.Sc.,
(Secretary of the Seed Improvement Committee).

[Read 11th December, 1919.]

This work was carried out in the Botanical Department of Melbourne University, as Government Research Scholar.

In studying the question of the longevity of cut flowers, the first thing to be taken into account is the reason or reasons which cause cut flowers to die, or to lose their characters as flowers by passing into the fruiting condition.

That is, flowers may undergo either :—

(1) Withering of the sepals and petals due to passage from the flowering to the fruiting stage.

(2) Falling of the sepals and petals due to the same cause.

(3) Abnormal premature withering.

The last cause is naturally the only one to be considered when dealing with the longevity of cut flowers.

Abnormal withering may be caused in various ways :—

(1) By the blocking of the vessels preventing the rise of sap and, as transpiration continues, resulting in a loss of turgor, followed by drooping.

(2) By self-poisoning, owing to an exudation of poison from cells near the cut surface.

In the work that has been done up to date no actual case of premature withering due to poisoning has been proved. The manner in which cases of possible poisoning were tested was as follows :—Some of the suspected material was thoroughly ground and squeezed, and an extract made, in one case by boiling in water, and in the other by soaking for a considerable period in cold water. Fresh flowers were then placed in the extract, which should contain the poison in concentrated form, but in every case the material in the extract lasted just as well as the control, proving that there cannot have been much, if any, poison present in the extract.

The most frequent cause of abnormal withering is, therefore, some form of blocking of the vessels with a resultant loss of turgor. That blocking does actually take place can easily be seen by sectioning the stem at short distances from the cut ends, and examining the vessels under a microscope.

This blocking may be caused by external factors, or by factors within the plant itself. The most common external cause is the development of bacteria in the water surrounding the stem. This is especially likely to happen if flowers are placed in dirty vessels, or vessels in which the water has been left standing for some time. The bacteria enter the vessels of the stem at the cut end, the sap being an attraction, and after a time form a complete block, preventing the ascent of water. This may happen to practically any plant, and the most effectual remedy is to change the water frequently, and by so doing the accumulation of bacteria is checked.

Internal causes of blocking are a great deal more difficult to discover and define. There may be an exudation of wound gum into the vessels, or the parenchyma cells surrounding the vessels may develop outgrowths which push their way into the lumina, and finally form a parenchymatous tissue completely blocking the vessels, and very effectively retarding the ascent of sap. This condition is known as the formation of a tylosis.

In order to prevent withering in these cases, it will be necessary to keep the vessels clear, either by preventing the exudation or the abnormal growth taking place, or by dissolving it as rapidly as it is formed. This will have to be done by placing the stem in some solution which will perform the required action without at the same time having any harmful effect on the living tissues of the plant.

The work was commenced with any plants that happened to be blooming at the time, and various well known household methods for preserving flowers were tested. Placing the stems in boiling water, removing the bark for some distance up the stems, and charring the stems, all proved equally unsuccessful with the flowers used. The only one found to be of the slightest use was in the case of dahlias, which, if inclined to droop, would when placed in boiling water, very often completely revive.

Chrysanthemums and wattles are very inclined to show sudden abnormal drooping, and in one or two cases this was proved to be due to the present of masses of bacteria blocking the vessels, while in others what seemed to be a gummy precipitate could be seen in the vessels by examining a section of the stem. Since the blocking and consequent withering take place very rapidly, it is most probably caused by an internal secretion of a gummy nature. If this is the case it should be able to be prevented by placing the stems, either in a solution which will cause a precipitation on the

walls of the vessels of the gummy substance directly it is formed and so prevent further exudation, or in a solution which will dissolve the exudation as fast at it enters the vessels.

Various tests were attempted to try and discover the solubility of the blocking material, but without success. If the material should be wound gum, which appears most likely, it ought to be able to be detected by testing with phloroglucin and hydrochloric acid, with which it should give a bright red colour, but no colour change was observable. A special stain for wound gum which should stain it in contrast to the surrounding tissues known as Hanstein's mixture, composed of equal parts of concentrated alcoholic solution of Fuschin and Methyl Violet, also gave no result.

Numerous tests for showing the presence of tannin were also attempted, especially on sections of Acacias, but although the presence of extensive tannin was shown in the cortex, medullary rays, and pith, the actual blocking substance in the vessels gave no definite tannin reaction.

The exact nature of the substance exuded from the surrounding cells into the vessels and causing blocking, therefore, remains doubtful, although it is most probably a form of wound gum which will not react to the colour tests.

Although the chemical nature of the substance exuded into the vessels remains undiscovered, an effective means was found of preventing the blocking in Acacias. It was found that if fresh specimens of Acacias, soon after being taken from the trees, are placed in a dilute solution of the non-poisonous heavy metals, no blocking occurs, and the flowers remain nearly perfect for a considerable period. The metal which proved most successful was lead, the nitrate, and the acetate being the salts most used, as they are the only two lead compounds easily soluble in water. Silver nitrate in dilute solution also proved fairly effective, but owing to its power of rapid decomposition it is somewhat unsuitable. Soluble mercury salts, presumably owing to their poisonous properties, proved rapidly harmful, while the other members of the group were not suitable for use.

The following tables give some idea of the effect that immersion of the stems in a weak solution of lead nitrate has on various species of wattle. It would be difficult to say exactly which day a certain mass of wattle flower actually died, therefore in the following tables the condition of the flowers at intervals of two, six, and fourteen days was noted. In a good many cases the flowers

did not shrivel and droop at all; apparently, if it had not been for other causes, they would have kept indefinitely, but in every case, after from ten to fourteen days, the specimens would become discoloured. This discolouring would commence with the part of the stalk actually immersed in lead nitrate, and gradually spread until it affected the whole stalk, leaves, and, lastly flowers, so that in no case could the flowers really be called fresh for more than fourteen days.

In many cases the articulation between the pedicels of the capitula and the stems become loosened, with the consequence that the capitula fall off very easily, although remaining quite fresh.

It will be seen that the exact effect of the lead nitrate varies with the different species; for example, no experiments with Acacia armata succeeded, and the effect on other markedly xerophytic species, such as juniperina and verticillata, was very slight. A good deal of variation is noticeable in the effect of the lead nitrate on different specimens of the same variety. In some experiments the control and the specimens in lead nitrate have lasted for an equally short period, whereas another experiment with the same variety will give a good result. In all cases where rapid withering has taken place detailed sectioning and examination of the stem shows blocking. There is presumably some undetermined factor which controls the extent of the exudation, and the effect which immersion of the stem in lead nitrate will have on this. It is possible that the length of time intervening between the time that the blossom is picked, and the time that it is placed in the solution will have a considerable influence on its longevity. Accurate experiments to determine this point have not yet been carried out; but it was noticed that in any case where the blossom had been kept for some time, and had begun to wither, the lead nitrate did not exert a reviving effect, but the specimen would remain in a drooping condition for a long time, whereas the control would completely wither. That is, the lead nitrate does not dissolve blocking already formed, but prevents any further exudation taking place. Another possible factor influencing the amount of blocking shown in the stem might be the age of the wood forming the vessels at the cut part. This point was also undetermined.

Tables to show the influence of varying strengths of lead and silver salts on the longevity of the blossoms of varying species of Acacias.

[The number of days quoted under each column indicates the number of days that the specimens remain fresh.]

Species.	Control. Days.	Lead nitrate .5% Days.	Lead nitrate 1% Days.
A. saligna	2	6	6
A. salicinia	2	2	2
A. montana	2	6	6
A. prominens	2	6	6
A. stricta	2	14	14
A. fimbriata	2	14	14
A. diffusa	2	14	14
A. neriifolia	6	14	14
A. leprosa	6	14	14
A. longifolia	6	14	14

	Control. Days.	Lead nitrate 1% Days.
A. rubida	6	14
A. pycnantha	2	14
A. longifolia, var. sophora	2	14
A. decurrens var. normalis	2	6
A. cultriformis	2	14
A. myrtifolia	6	14
A. dodonaeifolia	6	14

	Control. Days.	Silver nitrate 1% Days.	Lead nitrate 1% Days.
A. sclerophylla	2	6	6
A. venulosa	2	6	14
A. spectabilis	2	6	14
A. saligna	2	14	14

	Control. Days.	Lead nitrate 1% Days.	Lead acetate 1% Days.
A. retinodes	6	14	14
A. lophantha	6	14	14
A. armata	2	2	2
A. juniperina	2	6	6
A. verticillata	2	6	6
A. acinacea	2	2	2
A. neriifolia	2	14	14
A. melanoxylon	2	6	6

In order to prove that the solution of lead nitrate did actually prevent blocking in the vessels, and allowed a freer passage through the stems the following experiment was performed.

Two short stems of as nearly as possible the same length and diameter were fixed in a perpendicular position. To the upper end of each was attached a small rubber tube connected with a small reservoir, while to the lower end a small graduated flask was also connected by a rubber tube.

Reservoir A, attached to Stem A, was filled with water, and Reservoir B, attached to Stem B, was filled with a 1% solution of

lead nitrate. The reservoirs, which were the same size, provided an equal pressure on each stem, and should force an equal amount of liquid through the stems into the graduated flasks. The stems being of equal diameter, they should have approximately the same number of vessels, and unless blocking occurred in one and not in the other, the same amount of water and lead nitrate should pass through in the same time.

Experiment 1.—Time, one hour.

Stem A, water only, amount collected	.25 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

Experiment 2.—Time, 45 minutes.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

Experiment 3 (with same stem as Experiment 2).—Time, one hour 15 minutes.

Stem A, amount collected	.7 ccs.
Stem B, amount collected	7 ccs.

Experiment 4.—Time, two hours.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	3.5 ccs.

Experiment 5.—Time, three hours.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

These experiments show that the vessels are more open to the passage of lead nitrate solution than water. The viscosity of the lead nitrate solution is slightly greater than that of water, but its density is greater, and the greater head balances the higher viscosity largely. Neither factor would cause more than a 5 to 10% difference in the rate of flow, whereas the differences observed amount to 700 to 1000%, and this fact can only be explained by presuming that some form of blocking of the vessels intervenes to prevent the passage of water, but this is not developed when lead nitrate is passed through instead of water. This is proved by microscope examination of sections of the stems which have been used in the experiments. Stem A showed extensive blocking, whereas the vessels in Stem B were quite empty and with open lumina.

This method of preserving wattle blossom could be quite easily carried out in the household. A few crystals of lead nitrate to a quart of water should make a solution of a sufficient strength to preserve the blooms without having any harmful effect.

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Art. XVIII.—*The Endophytic Fungus of Lolium, Part I.*

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(With Plates XVIII. to XXVI. and 8 Text Figures.)

[Read Dec. 11th, 1919.]

Historical Introduction.

The fact, that grains of *Lolium temulentum*, L. (Darnel) contain a layer of fungal hyphae, situated between the aleurone layer and the fruit and seed coat, was demonstrated by Vogl (1) in 1898. In the same year Guérin (2), Hanausek (3), and Nestler (4), published papers dealing with this subject.

These earlier workers drew attention to the fact that the presence of the fungus in the grain is a fairly constant feature. Guérin examined samples of *Lolium temulentum* from South America, Asia, Africa, and Europe, and recorded that only three showed the absence of hyphae. He failed to note their presence in the embryo, although they were observed in the ovary before the fertilisation of the ovum. *Lolium arvense*, With., and *Lolium linicolum*. Sond., were also found to be fungal-containing, but he reported only one example of *Lolium perenne*, L., with the fungus. He suggested that the presence of the fungus in the Darnel grains is probably an example of symbiosis rather than one of actual parasitism.

Hanausek's results confirmed those of Guérin, and, in addition, he noted the presence of the hpyhae in the nucellus of the young ovary, where, he stated, it produced knots. This fact, he suggested, indicates a possible affinity of the fungus in question with the *Ustilagineae.*

Hanausek never examined a Darnel grain without finding hyphae in the usual position, but all samples of *L. perenne*, L. examined showed the absence of hyphae.

Nestler working along the same lines traced the distribution of the fungus in the seedling, and in the growing plant right up to the formation of the grain. He, in addition, tried to cultivate the fungus in artificial media with negative results. Only a few grains were found to be devoid of the fungus. He examined several

of the species of *Lolium*, including *Lolium perenne*, *L.*, but found that the hyphae were absent in all cases. It was suggested that possibly Woronin's "Taumelroggen" and the fungus of Darnel bore some relation one to the other, on account of their somewhat similar physiological action. At the same time, however, he called attention to the many differences which might be cited between the two.

Hiltner's (5) attention was drawn to the work of Hanausek and Nestler, and in 1899 he published a paper dealing with the function of the fungus found associated with Darnel. This he stated to be of a nitrogen fixing nature, and proceeded to verify the statement by experiment. He recorded that *Lolium temulentum* grew equally well in nitrogen-free and nitrogen-containing sand, and he was thus drawn to the conclusion that the above statement as regards its function is the correct one. The methods employed by Hiltner are open to criticism, and I shall refer to his work in a later part of this paper (pp. 284-285.)

Micheletti (6), 1901, worked mainly on the chemical side of the question. A paper, "The Seed Fungus of *Lolium temulentum*, L., the Darnel," by Freeman (7), appeared in 1902. Freeman found that samples of Darnel from various localities showed wide differences in the proportion between fungal containing and fungal free seeds. He correlated the absence of the fungus with certain morphological characteristics, viz., colour and shape, although he indicated that in a few cases this correlation was not evident. Perhaps the chief point in his paper deals with the mode of entry of the fungus into the embryo. He described an isolated patch of hyphae at the base of the groove on the inner side of the grain. This patch he called the "infection layer" and he stated that it was from this layer that infection of the embryo took place. The course of the hyphae, according to his observations, was always intercellular, and penetration of the aleurone layer by the infecting hyphae took place at the junction of several cells. In all grains examined where hyphae were present in the embryo they were also found in the grain, and all the evidence was negative as to the possibility of their presence in the embryo and absence in the grain. However, he cited one doubtful case as regards this converse statement.

The distribution of the fungus in the growing plant was noted, and in dealing with the inflorescence and ovary he described in detail the development of his "infection layer."

All attempts to cultivate the fungus in artificial media were unsuccessful.

In conclusion he pointed out that Guérin considered the relation between the two organisms, one of true symbiosis; he agreed with this idea, but added, "the large hyphal layer of the grain, and the occasional penetrations of the endosperm, suggest vestigial indications that the action of the fungus is, or has been, at times injurious to the endosperm of the plant. Otherwise the fungus seems ordinarily to exert an almost stimulating influence on the host."

Freeman examined 30 grains of *Lolium perenne* L., and found only 5 contained the fungus. Of 59 grains of *Lolium italicum*, Braun, 2 alone showed the second organism, while of 25 grains of *Lolium linicolum*, Br., the full number gave positive results.

Another paper by Nestler (8) appeared in 1904, but it throws little further light on the problem. Fuchs (9), 1911, viewed the subject from the chemical standpoint, and finally, in 1912, a research by Buchet (10) was published, but, unfortunately, I have been unable to obtain this paper in Australia.

The erratic occurrence of the fungus in both *Lolium temulentum* and *Lolium perenne* recorded by these investigators does not tend to support the idea of a symbiotic association, but rather stresses the probability of its parasitic nature. The investigations described in the following paper were carried out in order to test these results for those grasses grown in Australia, and also to attempt to elucidate the actual relation between the two organisms. In attempting to further our knowledge of the relation between the grass and its associated fungus, I have limited myself mainly to a study of *Lolium perenne*, as practically no work has been done on this grass, and, in addition, it is a much more convenient form for obtaining embryological material. As far as time permitted I have compared this form with *Lolium temulentum*, and the results recorded in this paper are true for both forms. Perhaps a few minor differences may be determined later, but the main points are undoubtedly true for both grasses.

Methods.

Microtome sections were employed in the examination of the mature grains. The grains were soaked in distilled water for several hours, and then placed in a fixing fluid. During the early part of this work, Carnoy's fixing solution was used. Owing to the starchy nature of the endosperm, it was difficult to get good results,

but if a paraffin with a fairly low melting point be used, it was found quite possible to obtain good and serial sections, after using this fixing reagent. At a later stage Bouin's fixative was employed, more particularly when dealing with the later stages in the development of the grain. It was quite easy to obtain absolutely entire sections after the specimens have been fixed in this way. The disadvantage lies in the fact that the starch in the endosperm was not well preserved, and also after this fixative the staining reactions, with the stains employed, do not seem to be as brilliant as they are following upon Carnoy's fixative.

The ether-freezing microtome was not satisfactory, owing to the difficulty in obtaining serial sections, and it was generally necessary to do this. Again, it was impossible to obtain as thin sections in this manner as with the paraffin method.

Hand sections were practically useless. They can only confirm the presence of the hyphae in the grain, but evidence as to their absence cannot be drawn from them.

The stain most generally employed, in fact, solely, as regards the mature grain, was aniline gentian violet.[1] In using this stain care must be taken to see that it is always fresh, as it does not keep well. Its staining capacity diminishes rapidly after several days. This stain was washed out with Gram's iodine water, then with absolute alcohol. Sections were next cleared in clove oil, and mounted in balsam.

Excellent results were obtained with this stain, the hyphae for the most part being stained a brilliant bluish purple, and the endosperm reacting to the iodine.[2] It far exceeded any other stain I have tried, among them being Haidenhain's haematoxylin, aniline safranin, erythrosin, aniline blue, etc. The aleurone cells for the most part and the cells of the scutellum and embryo do not stain, so that the hyphae present in these tissues stand out in striking contrast to the colourless cells around them.

This stain, used by itself, was only useful when dealing with the mature grain. In studying the embryology of the grasses in question it was necessary to counter-stain. Sections of the ovary before, and at the time of fertilisation, were stained with Bismarck

1. One Soloid tabloid of gentian violet dissolved in 7 ccs. of abs, alc, and 63 ccs. of water containing 2.8 ccs. of aniline solution.

2. The colourisation of the endosperm by the iodine is, of course, not permanent, although the hyphae retain the violet stain well. This is certainly a drawback to the method, but it is more than compensated for by the excellent results obtained, which, indeed, are not approached by any other method.

brown, followed by aniline gentian violet; later stages were also treated in the same way. In addition, some of the later sections were stained with congo red. These were first stained with aniline gentian violet, followed by Gram's iodine water, and finally by congo red. This stain washes out very readily in the alcohols, so it was found necessary to use a watery solution of congo red, and to wash away excess with water, then to drain off as much of the water as possible, and transfer immediately to clove oil. If the sections be left on the water oven at a temperature of 45°-50°C., they will clear perfectly well in from 1-2 hrs., and they can then be mounted in balsam and prove to be quite permanent.

The mature grain.

My aim at first was to make a record of the grains of both *Lolium temulentum*, and *Lolium perenne* examined, and to note the number of fungus-containing and fungus-free seeds.

After examining a large number of grains, I have been forced to the conclusion that it is impossible to distinguish macroscopically grains containing the fungus from those devoid of it (if any). The colour difference cited by Freeman cannot be regarded as a distinguishing feature.

Nine grains were chosen from a sample of Darnel obtained from Northam, Western Australia. Of these 4 were very dark in colour, 2 more or less intermediate, and 3 a pale straw yellow, but all of the nine showed a dense hyphal layer situated between the aleurone layer and the outer testa and pericarp. This is but a single example of many similar series. As the work proceeded it became more and more evident that both colour and size of grain were quite independent of the fungal constituent.

When commencing this record hand sections were used, as it was possible to handle a large number of fruits in a comparatively short time, by this means. Sometimes these hand sections revealed a grain apparently fungus-free—i.e., no definite layer of hyphae could be seen in the usual position in the grain. These, when obtained, were frequently microtomed, and fine but distinct fungal hyphae were found penetrating the scutellum, so it seemed impossible to decide whether a particular grain was devoid of the fungus unless serial sections were obtained sufficiently thin to enable these fine threads to be demonstrated. Although hand sections are useful in demonstrating the presence of the fungus, they cannot be accepted as evidence in regard to its absence.

The following results show that *Lolium perenne* is just as striking an example of a fungus-containing fruit as *Lolium temulentum*, and that the number of either grains devoid of the fungus is remarkably small. In fact, they suggest that probably all grains of Darnel and English rye grass contain this second organism, and failure to discern it in some grains is due to the fact that it is present in such minute quantities in the mature grain that it needs special care and staining to bring the hyphae out, or, as this paper proceeds, a second alternative will be considered (p. 293).

Lolium temulentum, L.

Locality	No. of grains examined	Fung. pres.	Fung. abs.
Victoria	93	93	—
Northam, W. Aust.	9	9	—
Katanning, W. Aust.	27	27	—
Kew, England	31	31	—
Cambridge, England[3]	9	9	—
Total	169	169	

Lolium perenne, L.

Locality	No. of grains examined	Fung. pres.	Fung. abs.
Victoria	53	53	—
Cowra, N.S.W.	12	12	—
New Zealand	4	4	—
South Africa	18	18	—
Scotland	11	11	—
Ireland	17	17	—
Total	115	115	

Although former workers have recorded the presence of the fungus in *Lolium perenne*, previously it has been thought to be very sparingly distributed in this species. The above results show that this is not actually so. It has also been suggested that the toxicity of Darnel is due to its fungal component, but since English rye grass shows a regularly occurring hyphal layer as well as Darnel, this suggestion

3. The "seeds" of this Cambridge sample were much smaller than those of any of the Australian samples. Frequently also on hand-sectioning no hyphal layer was evident, but several of the grains were microtomed, and further examination then showed distinct hyphae in the scutellum and embryo. Possibly the plants yielding the grain were grown under conditions which did not favour the luxuriant development of the fungus, so that the absence of the extra-cellular hyphal layer was more common in this sample than is usually the case. Only these grains which were actually microtomed are included in the above list.

does not seem to be a feasible one. Of course it might be argued that the two grasses contain different species of fungi, one of which might be toxic, the other harmless. The actual identity of the fungi obtained from the grains can only be established when they are grown artificially, and the sporing stage obtained, but as far as one can judge by comparing the two forms, they are very similar, and are certainly very closely related if not actually identical. Seemingly the explanation of the cause of the poisonous nature of Darnel must be looked for elsewhere, and is not to be furthered by a study of the fungus found inhabiting it.

Freeman, when discussing the fungus in the embryo of the grain, records some experiments which were undertaken in order to investigate the function of the nucellar layer of hyphae, although it is not quite clear what bearing they have on this point. He grafted embryos of *Lolium temulentum* on endosperms of *Lolium perenne*, and vice versa, the grains having previously been sterilised, and all manipulations carried out under sterile conditions. Thirty-four grafts of *Lolium perenne* embryos on *Lolium temulentum* endosperms were made, and of this number eighteen germinated. He examined two of these seedlings, and found both contained hyphae, from this he argued it was very probable that "hyphae from the *infection layer* of the *L. temulentum* grains were able to gain entrance to the embryos of *Lolium perenne*." These experiments really lead nowhere, for the hyphae are already in the rye-grass embryos before grafting on any foreign endosperm, and their presence cannot possibly be due to infection from the nucellar hyphal layer or from his localised *infection area*.

Distribution of the fungus in the grain.[4]

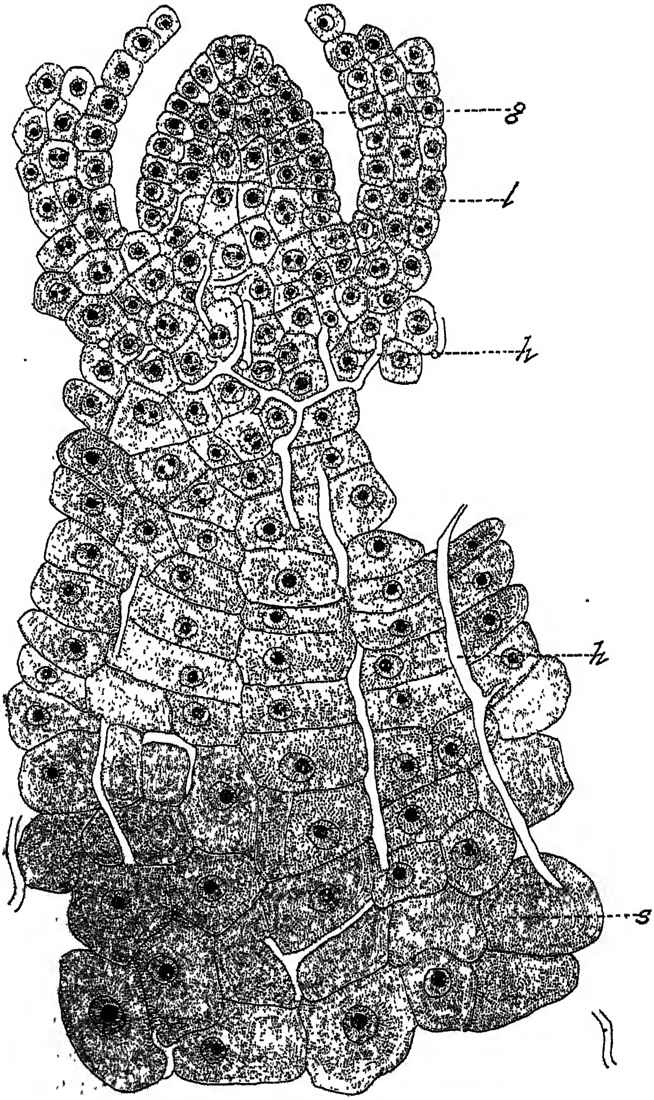
Many grains of *Lolium perenne* were sectioned with a view to determining the distribution of the fungus in the fruit. Transverse sections taken at different levels are shown in Plate XVIII., Figs. 1-3. The yellow line illustrates the distribution of the fungus. A transverse section at the distal end of the grain, Fig. 1, shows the hyphal distribution to be co-extensive with the aleurone layer. A

4. Following upon Brown and Morris (11), I have adopted the following terminology in describing the grain. The furrowed side of the grain is the *ventral* surface, the side opposite to this the *dorsal*. The embryonic end is called *proximal*, while the stigmatic end, or that portion remote from the embryo, is *distal*. A section passing through the ventral and dorsal surface is a *sagittal section*, while the longitudinal section at right angles to this is a *coronal* section. The sagittal plane which divides the grain into two equal halves is the *median sagittal plane*. A section at right angles to both sagittal and coronal planes is *transverse*.

transverse section nearer the proximal end of the grain, as is shown in Fig. 2, would cut through the scutellum. Such a section shows that the hyphae occur between the endosperm and the scutellum wherever the tissues are in contact, and hyphal penetrations into the scutellum may and do take place at any point over this area. The hyphae in addition extend even past the limits of the aleurone layer, and penetrate the scutellum on its outer exposed dorsal surface. A transverse section at the extreme proximal end of the grain, Fig. 3, passes through the embryo, but the starchy endosperm is no longer included in the section.' Even at this level the hyphae surround the scutellum, as is indicated by the yellow line in the figure. The coronal plane is perhaps the best for demonstrating the distribution of the fungus in any one section (Plate XVIII. Fig. 4), the occurrence of the fungal layer between the scutellum and endosperm at all points of contact and the extension of the fungal tissue on the dorsal proximal surface is clearly seen.

Plate XVIII. Fig. 5, shows a median sagittal section illustrating the same points and, in addition both of these latter sections shew the distribution of the hyphae in the embryonic area. The scutellum is often very richly traversed by fine fungal threads, and they are not restricted to any special area, but occur more or less uniformly right through the tissue. Some grains show these threads more readily than others, but a study of the embryology of the grain will suggest that this might often be the case. The hyphae are readily discernible in the growing cone; their presence here has been pointed out by the earlier workers. (Text-figure 1.). The above facts are also true of *Lolium temulentum*, but it is much rarer in this case to obtain a scutellum so markedly inhabited as in *Lolium perenne*, and in any case the threads are generally finer. In several examples of *Lolium perenne* I have found hyphae present in the radicle, but they are not generally evident in this region.

Freeman raises the question—How does the fungus obtain entrance to the embryo? As an answer, he devoted a large part of his paper to a description of a localised patch of hyphae, which he termed "*the infection layer*," and to its mode of origin. He says that on the ventral proximal end of the grain there occurs an isolated patch of hyphae which penetrates between the aleurone cells and cells of the scutellum, and thereby gain entrance to the embryo when it is fairly advanced in its development. He states that on the dorsal surface of the grain the hyphae do not extend to the end of the aleurone layer. To



Text-Figure 1.

Growing point of an embryo from a *Lolium perenne* grain. The section was cut obliquely and includes only the growing point =g; young leaves=l; and scutellum=s; hyphae=h. × 850 diam.

quote directly: "It is not impossible perhaps that infection may, in exceptional cases, take place from this side of the scutellum (dorsal); but, if so, it occurs very seldom. I have seen no evidence either in the mature grain or in the developing ovary to indicate that such an infection is ever accomplished."

My observations permit of a different answer to this question. Hyphae occur at the junction of the scutellum and endosperm, not only near the ventral surface (Freeman's infection layer), but wherever these tissues are in contact I was unable to demonstrate the existence of an isolated patch as described by Freeman, Furthermore, it is impossible to agree with the statement that the hyphal layer does not reach the end of the aleurone layer on the dorsal side of the grain. As is shown in Plate XVIII. Figs. 2-5, hyphae can and do occur right round the periphery of the embryonic area.

These facts in themselves are interesting, but they do not answer our question. At a later stage, in this paper, it will be shown that *infection* of the embryo takes place at a very early stage in development, and that the distribution of hyphae in the mature grain has no bearing on this point, but is a result of the special function carried out by this partner in the development of the grain.

It is only fair to emphasise the fact that Freeman dealt only with *Lolium temulentum* when working out his idea of an infection layer, and that this criticism is based *mainly* on work done on *Lolium perenne*. However, if the facts demonstrated in the embryological section (pp. 267-281) are true, they apply equally well to both forms, and it becomes abundantly clear that the distribution in the adult grain is not associated especially with the *infection* of the embryo as Freeman suggests.

Previous workers have described the hyphal layer itself in detail. Australian grown grains of either grass seem to shew a very rich growth of hyphal tissue. Some grains of Darnel grown in the University grounds, Melbourne, had an average layer of 31.6 u. Grains of English rye in many cases showed a layer quite as broad as that shown by an average Darnel, but in both the width or extent of the layer is extremely variable, depending largely on the activity of the fungus during the period between fertilisation and formation of the seed. Aniline gentian violet, followed by Gram's iodine water, was used solely for staining the adult grains. The hyphal layer does not stain uniformly, however, with this stain, some portions of the hyphal threads reacting to the violet colour, other parts remaining colourless. This variation in the staining

properties was displayed by different parts of the same hyphae, the coloured portions being interrupted by colourless, in a very irregular manner. In order to ascertain whether these unstained segments contained protoplasm or were devoid of contents, and thus remained unaltered by the stain, sections were submitted to a second stain following upon gentian violet. Congo red was chosen, as it stains the cell walls, and also the protoplasm The result was that the former uncoloured sections were stained with the red, and displayed dense contents just as is the case with the coloured segments The difference in the staining capacity is probably due to the presence of ferments in certain parts of the hyphal network wherever the ferment is present in any quantity, then will the "blue" stain be evident. Colour is lent to this idea by the fact that the aleurone layer shows the same staining reactions as the hyphal layer. The majority of the cells do not react to the violet stain, but certain of them stand out markedly from the rest, for they stain densely and form very striking portions of the section. The number of such coloured cells varies in each individual grain. In addition, the scutellum repeats the above phenomenon. In this case, the "blue" cells are generally restricted to the epithelial layer of this tissue.

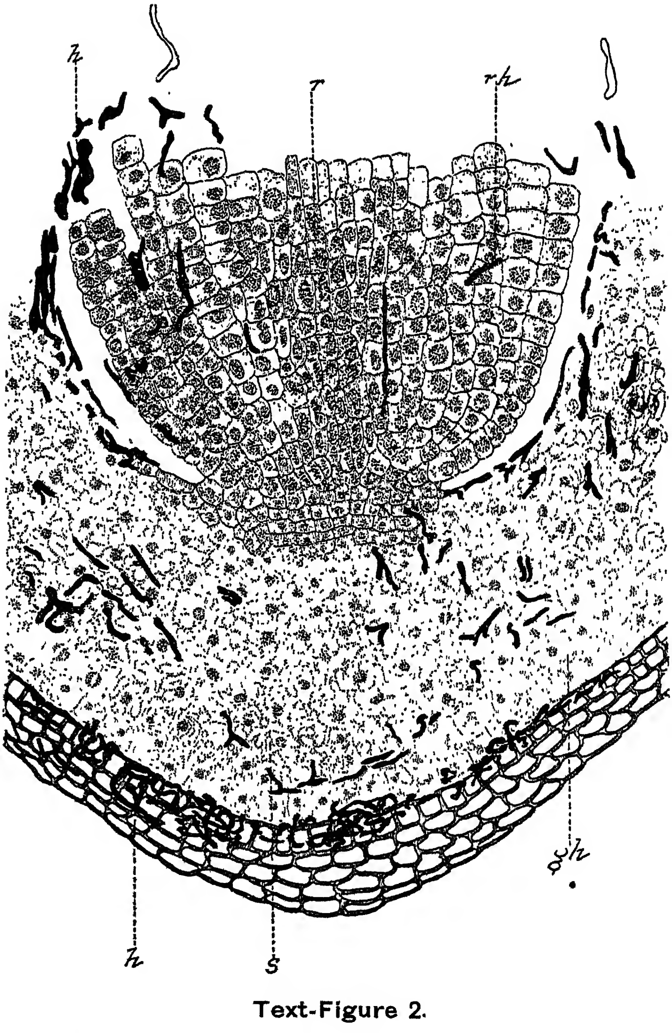
Brown and Morris (11) have shown that in *Hordeum vulgare* the secretion of diastase is located in the absorptive epithelium, and in a later paper Brown and Escombe (12) that in addition, the aleurone layer is capable of bringing about marked changes in the endosperm when this is separated from its embryo, and placed under favourable conditions.

The distribution of the active ferment-secreting cells therefore, agrees with the staining reactions described above, and supports the view that the coloured segments of the hyphae contain either an enzyme or its fore-runner, and this conjecture is further strengthened by the later embryological work.

When examining a sample of English rye grass from Ireland, a specimen was occasionally found showing hyphae (which for the most part stained with gentian violet) invading the starchy endosperm. Freeman records a similar distribution for grains of *Lolium temulentum* from Ghent. A careful examination of the aleurone layer of such a grain showed that the hyphae were also running riot here. Instead of the usual inter-cellular course, many hyphae could be made out actually passing into the cells, and in many cases a single hypha could be traced entering and leaving

as many as three cells. As is well known, the cell walls of this layer are thick, and also pitted. The hyphae enter through these pits, and thereby gain access to the cell (Plate XIX. Fig 5). Sometimes the opening in the wall of the aleurone cell was smaller in diameter than the penetrating hypha; when this was the case a conspicuous narrowing was noticed at the point of entrance, but on the far side of the pit the hypha again attained its previous size. In addition the scutellum showed an extraordinarily large amount of the fungus. Here the intra-cellular course was also very evident (Plate XIX. Fig. 4). Many of the scutellar cells stained vividly; such cells were seen to be fungal containing. The entrance to the cells was gained through pitted walls, as is the case in the aleurone layer. The remaining cells of the scutellum were normal, and the grains did not seem to be any the worse for this exceptional behaviour on the part of the fungus. In such abnormal grains the hyphal layer was present as usual. There is no doubt that the hyphae invading the cells are the same as those composing the extra cellular layer.

These phenomena were not confined to the sample from Ireland, one of English rye grass from South Africa also contained certain grains showing an extraordinary distribution and growth of the fungus. As before, both the aleurone layer and the scutellum were permeated by intra-cellular hyphae. In one particular case the scutellum, which normally is packed with aleurone grains, appeared to consist of a dense sclerotial-like mass of threads. The bulk remained colourless, and they resembled "ghosts," or casts, of former more virile hyphae (Text figure 2). They are represented in the text figure as dotted lines, and they completely filled the whole of the scutellar tissue, although the cells composing it were not distorted or enlarged in any way. This section cut in the coronal plane) and the others accompanying it, were later stained with congo red; it was then easier to decipher these ghost-like contents of the scutellum. Many were cut transversely, but owing to a large amount of twisting some were seen running lengthwise through the tissue for a short distance. They probably represent fungal hyphae, which were numerous at certain stages in the development of the grain, carrying a special food supply to special parts, and in giving this up to the host-plant they have undergone a partial dissolution, which was not completely carried out in these few exceptional cases by the time the grain reached maturity.



Text-Figure 2.

A longitudinal section through the radicle, and a portion of the scutellum of a grain of *Lolium perenne* (Ireland). This was an abnormal grain. r = radicle, rh = hyphae in radicle, s = Scutellum, gh = ghost-like hyphae forming a sclerotial like growth in the scutellum which was nevertheless perfectly formed; h = hyphae staining with gentian violet. × 103 diam.

Text-figure 3 illustrates the stigmatic end of the same grain (a coronal section not cut in the median line shows portion of the

Text-Figure 3.

A section of the stigmatic end of the same grain as text fig. 2: a = aleurone cells, the outlines of which are distorted by abnormally large intercellular hyphae; h = intercellular hyphae, h = intra-cellular hyphae, w = wall of aleurone cell. × 1000 diam.

aleurone layer at this end of the grain cut tangentially, and therefore it does not appear as a single layer of cells.) Interpolated between the aleurone cells, lying in the inter-cellular spaces, altering their whole contour, are outlines of hyphae, which seem to be swollen, somewhat gelatinised, and in a state of disorganisation. Similar bodies were also visible in the matrix of the cells themselves.

These occurrences lead me to believe that at some stage in the life of the grain the hyphae were intra-cellular, and that in the few aberrant cases met with this embryological condition persisted in the mature grain.

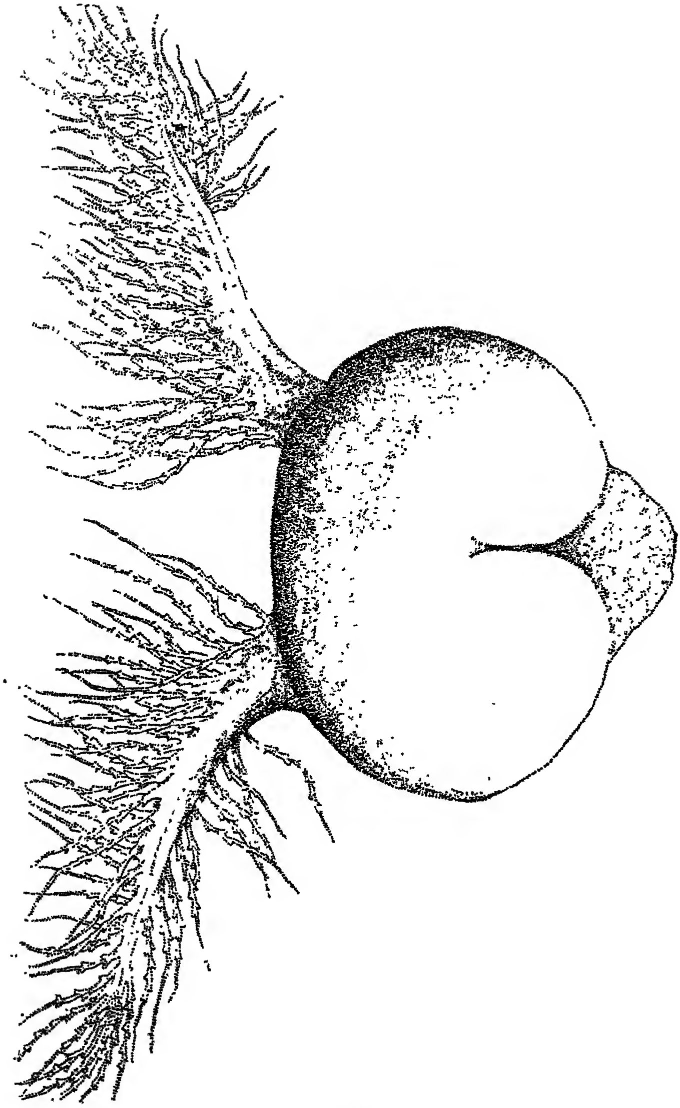
Development of the Ovary from the Flowering to the Fruiting Stage.

It is convenient to divide this portion of the paper into sections, and to consider the relation of the fungus to the grain, at certain definite stages in its formation. This relation becomes very pronounced and characteristic, either just about the fertilisation period or immediately afterwards, and from here to the final stages is most intimately associated with the changes taking place, resulting in the formation of the endosperm, with its aleurone layer, and the various parts of the embryo.

Stage A.

Text-figure 4 illustrates the external appearance of the ovary at the flowering stage just prior to fertilisation. It is drawn from the ventral surface, and shows the stigmas arising from the dorsal side, the bi-carpellary nature of the fruit is indicated in the figure. The ovum lies directed towards the proximal end of the ovary. I have designated this period Stage A.

Hyphae are present in the carpels from their earliest inception, but it is only at about this stage that their intimate relation with the ovarian tissues of the grass is evident. They enter the ovary at the stalk end, and branch through the carpellary wall. They are generally more abundant during the earlier stages at this end than at the distal stigmatic end. These hyphae characteristically accompany the vascular tissue of the stalk, and are to be seen in very close proximity to the annular and spiral vessels running in this area. (Plate XXI. Fig. 4.) In many of the sections numerous small lateral buds on the hyphae suggested haustoria, but they may be minute lateral branches just being caught in the section. The



Text-Figure 4.

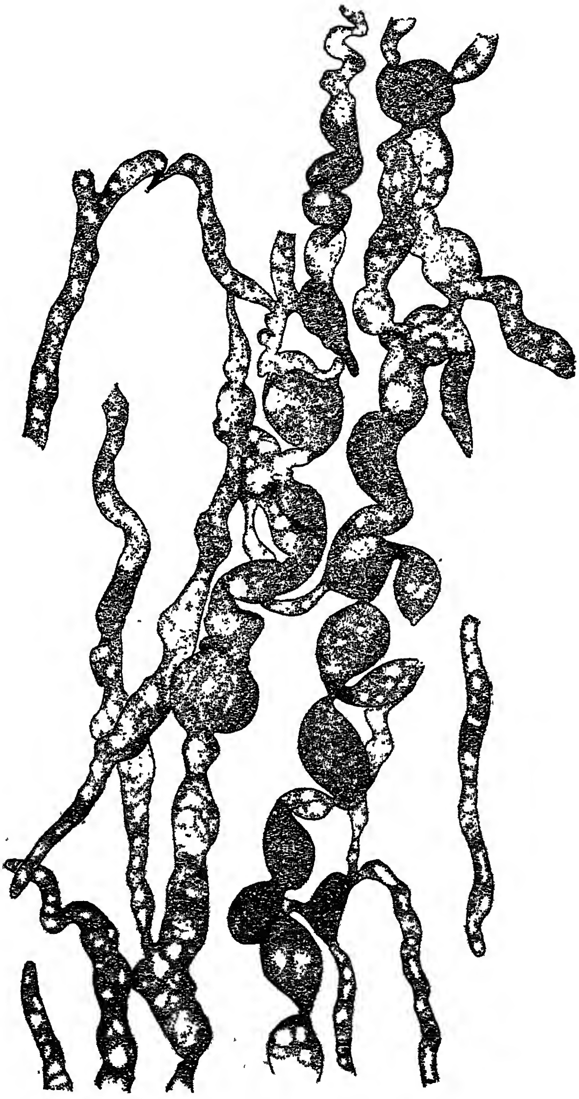
External appearance of the ovary of *Lolium perenne* at Stage A. × 15 diam.

cells of the carpellary stalk do not contain starch, and many of them stained deeply with the gentian violet after counter-staining the sections with bismarck brown. These blue cells were always plentiful in this region; such cells have been invaded by the fungus, and their contents probably used for its own nutrition. They always stain deeply, and the hyphae in their vicinity do likewise. If the cells do not stain too darkly, it is possible to observe fungal threads forming a network in the lumen of the cells, many of the threads being exceedingly fine. The position of these cells is shown in Plate XX. The cells are not enlarged, and apparently only differ from those around them by their different staining properties. The cell walls in this area are pitted; whether this is the normal condition or whether the pit has resulted from a secretion of the fungus is a debatable point.

The lateral walls of the carpel are packed with small compound starch grains, and in this region the hyphae only occur between the cells. They run in all directions, but are, as far as I have observed, strictly inter-cellular in this position, at this stage. However, when the stigmatic region is reached they seem to get the upper hand, and a large number of cells become their prey. These cells are also starch-containing, and when so intruded upon they immediately react to the violet stain. Sometimes the whole of this area will appear a dense violet colour, for the great majority of the cells in this part are attacked at this period. When the cell is first invaded, the starch is seen to become swollen and disorganised, and loses its power of reacting to the iodine wash used in preparing the sections (Plate XXI., Figs. 2 and 5). The fine hyphal threads wrap round the starch groups, and even enter between each individual grain (Plate XXI. Fig. 5), apparently digesting them. There is no doubt that these cells are suffering at the hands of the fungus, and that their contents are being transferred to this fungal system. Some of the cells show an entire absence of starch; they appear to be practically empty, and somewhat collapsed. These have been invaded at an earlier stage, and yielded their contents in a similar way. The stigmatic tracts present in the carpel wall generally show hyphae in abundance; they extend right into the stigmas, and even here become intra-cellular, but do so probably only after fertilisation has taken place, when the function of the stigmas has been completed.

Occasionally, the base of a staminal filament remained attached to the ovary during sectioning, and hyphae were found to extend

into this region. One or two examples were obtained, showing such hyphae in a much convoluted condition. Parts of the thread were swollen and bladder-like, with sharp constrictions at intervals. The contents, however, were the same throughout the length of the thread, showing no signs of spore formation. (Text-figure 5.)



Text-Figure 5.

Hyphae from a staminal filament shewing sharp constrictions occurring at intervals along their length. × 1700 diam.

While these changes are proceeding in the carpel wall, the hyphae in the developing ovule are not quiescent. They keep pace with the growth of the ovule, and until the embryo-sac is at the 8-celled stage they simply run between the cells of the nucellus, ramifying in every direction. They extend right through the nucellar tissue completely surrounding the embryo-sac. Freeman, when discussing the ovary of *Lolium temulentum* at this stage, states that hyphae are completely wanting on the outer dorsal surface towards the embryo-sac end, stopping at about the level of the antipodal group. If this is so, it is difficult to see how hyphae come to be present in this position in the mature grain. As far as I have observed they are uniformly distributed through the inner layers of the nucellus, but do not generally extend into the very outer layers until later in development. The dual staining properties are shown by these hyphae, but the great majority of them will pick up the purple stain.

The first indication of any change in the relation between the fungus and the cells of the ovule at this stage is the tendency for the hyphae to form knots (Plate XXI. Fig. 3). These are especially striking if the sections are cut rather thicker than those to be used for detailed high power examination. Hanausek described the occurrence of knots (Knäuel) in the ovary of Darnel, and figured them: I have been unable to obtain his original paper, only abstracts without figures being available. He offered the occurrence of these knots as evidence in favour of the fungus being related to the *Ustilagineae*. Freeman says: "I have found no such knotting of hyphae to indicate the commencement of Ustilagine spore formation." These knots undoubtedly do occur, but are rather to be regarded as the first stages in the penetration of the nucellus cells. The hyphae arch round all sides of the cell before entering it, and as they generally invade two or three adjacent cells simultaneously, this arching gives the knot-like formations above described. I do not think they afford any clue to the actual systematic position of the fungus in question. Since they are just on the point of attacking a cell they are rich in ferments and always stain vividly.

Cells showing a later stage of invasion are also present in such an ovule. Lateral branches arise from these enfolding hyphae, which penetrate the cell wall and pass into the substance of the cell itself. It soon becomes filled with a dense network of threads, and in this condition forms a most striking part of the

section, for such cells are the only members of all the nucellar tissue, which will stain in the same way as the fungal system. (Plate XXI. Fig. 1). They stand out in contrast to the background of normal, unattacked nucellar cells.

It is difficult to determine whether the hyphae actually apply themselves to the nuclei, but it is readily seen that the nuclei do undergo a definite change, becoming large and somewhat distorted, and at this stage will stain uniformly with the violet dye. These fungal-containing cells may occur in any position in the nucellus, but at this stage they are few in number, and are generally to be found at the end of the ovule furthest from the micropyle. They become more abundant after fertilisation occurring in any part of the nucellar tissue.

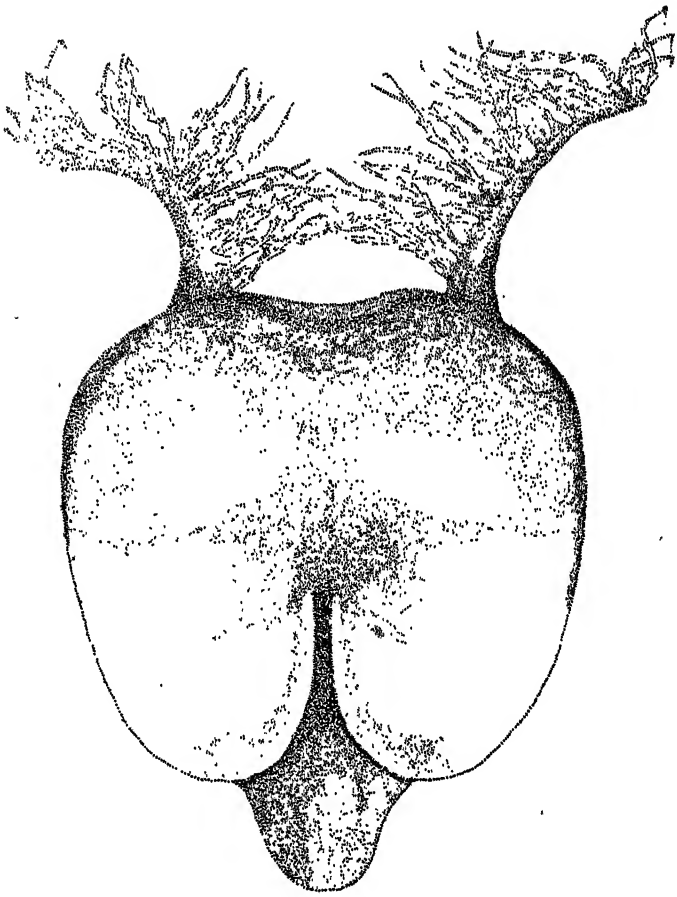
The embryo-sac at this stage is ready for fertilisation, and it agrees with the rest of the ovule in containing the fungus. The protoplasmic lining of the sac carries the hyphae. They run rather sparingly along the sides, and at the distal end of the embryo-sac, but are more abundant at the proximal end in the vicinity of the ovum. They are in close connection with both the synergidae and the egg-cell, and enter into the substance of the latter at this early point in the development of the grain. (Plate XXI., Fig. 6.) Previously it has been thought that "*infection*" took place at a much later stage, after the differentiation of the growing cone, when the formation of the embryo was fairly advanced. It has been suggested that the entrance of the fungus into the embryo was due to the chemotactic influence of the growing apex. My observations show that the fungal constituent is present in the ovum before any divisions have taken place, and that the formation of a special layer in the grain for the purpose of infecting the embryo at any specified period is not necessary.

Stage B.

Text-figure 6 illustrates the external appearance of the ovary after fertilisation, and at the commencement of endosperm formation. The elongation of the ovary which accompanies this change is beginning to be apparent. As in Stage A, it is drawn from the ventral surface, and shows the same features as before.

If an ovary be sectioned at approximately this stage, our knowledge of the relation of the fungus to the grass is considerably augmented.

The hyphae are still active in the carpel wall. The cells composing the distal area of this wall are attacked by the fungus, their



Text-Figure 6.

The external appearance of the ovary of *Lolium perenne* at Stage B. × 15 diam.

starchy contents are disorganised and absorbed into the hyphal system. The collapse of these cells enables the ovule to encroach on the space formerly occupied by them, and elongation of the developing grain thereby results. At this period the ovule does not increase markedly in breadth, and so the cells composing the side walls of the carpel are not yet invaded, the activity of the fungus is, as in Stage A, more evident in the distal region.

The most noticeable change occurs in the ovule itself. The fungus is responsible for the disorganisation of the nucellus.

Thriving on the nutriment obtained from these cells, and also on that obtained from the carpellary wall, it increases tremendously in amount, invading and attacking every portion of this tissue. (Plate XXII. Fig. 1.) This figure represents the hyphae massed together in this area. For the most part it is difficult to discern the outlines of the disorganising cells, except at the edge of the ovule, where they are still intact, although, unlike the previous stage, the hyphae have spread now into these outer layers. The nuclei of the cells of the nucellus persist for some little time after invasion, but they become enlarged, and stain uniformly, as shown in the figure.

The type of branching of the hyphae is very characteristic. (Plate XXII. Fig. 2.) The branches are given off almost at right angles to the main thread, and at their point of origin a slight swelling generally occurs. They are strongly septate, and rich in protoplasmic contents, and they show numerous vacuoles and well marked nuclei. If the sections are stained only with gentian violet, followed by Gram's iodine solution, the majority of the hyphae in these regions stain deeply, but the colourless portions noticed both in the adult grain and in the ovary prior to fertilisation are still present. In order to stain these segments sections at this stage were subjected to congo red, after staining in the above manner. Such treatment made the study of the endosperm much simpler.

The embryo-sac as a result of the stimulus of fertilisation has enlarged considerably, the enlargement being accompanied by the appearance of endosperm. The formation of this tissue is at first most active at the proximal end of the sac, in the vicinity of the ovum. On the dorsal proximal surface it forms a complete plate of tissue, the distal extremities of which are separate and considerably narrowed. These dip towards the ventral surface, and in section appear as two bands of tissue, from one to two cells in width, each being surrounded by nucellus.

The cells of which the endosperm is composed are highly protoplasmic, and contain large nuclei. Starch has not, as yet, been laid down in them. The endosperm is formed at first by a process of free cell formation. This soon ceases, and further growth takes place by the repeated division of the outer layer of cells, and thus the tissue grows, and gradually assumes its mature condition. This mode of growth is more easily followed at a later stage, so further reference will be made to it when dealing with Stage C.

Until the endosperm commences to be formed, the fungus has been increasing in amount at the expense of the nucellus, etc. This increase is only a temporary one, for the hyphae now grow in close contact with the endosperm cells. They enter them when the cells are young and not fully formed, and are here seen to become disorganised. The food material thus gained by the grass is used in the preparation of the reserve store of food, which is later to be deposited in this tissue. Plate XXII., Fig 3, shows a portion of the endosperm and the accompanying hyphae. This section was stained with congo red, and the hyphae and protoplasm stain in the same way. Plate XXII. Fig. 4, also shows the close union between the fungus and the grass. This section was stained only with gentian violet, and the hyphae could be traced more readily in the cell itself. Many of the disorganising threads running in the host cells stained blue, and are shown in the figure, the cells themselves remaining unstained. Plate XXII., Fig. 5, repeats the structure shown in the two previous figures, but in addition it shows extremely well, lateral branches, which arise from a hypha running parallel to the length of the endosperm, and which enter adjacent cells of this tissue, yielding up their food to the embryo grass plant.

The fungus is most abundant in the region of the ovum, due probably to the fact that the lumen of the embryo-sac begins to fill first around the embryo. In this region the cells are long and crescent shaped, and have very dense contents.

The synergidae are still present, and their absorption is no doubt the result of the activity of the fungus, a fact which may help to explain the pronounced growth of hyphae always present in this position.

The ovum is still undivided, although it has increased in size and the cytoplasm has become vacuolar.

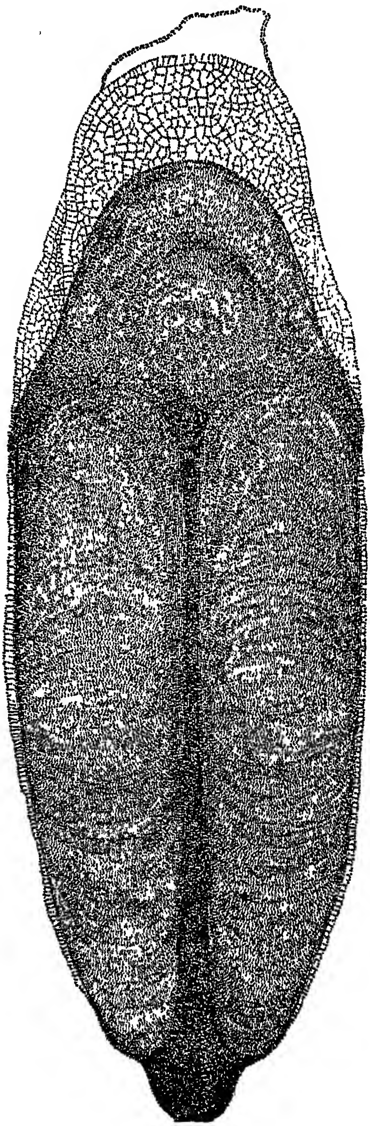
In the intermediate stages between B and C, the division of the ovum and the subsequent growth of the embryo are points of interest. The first division of the egg is generally transverse, at right angles to the pro-embryo, and each cell usually contains a well-marked vacuole. The fungus ramifying in the nucellus in this part of the sac comes into direct contact with the endosperm, which forms a lining to the pocket in which the embryo grows. The hyphae are unusually abundant, and are actively transferring food-material from the various parts of the carpel to the endosperm in this area. (Plate XXV., Fig. 1.) These cells are later absorbed

by the growing embryo, which, therefore, ultimately benefits by this concentration of hyphae. The cells of the pro-embryo also receive hyphae directly. Plate XXV., Fig. 3, shows a more advanced embryo. The dermatogen has just been cut off, and the hyphae are seen to enter right into the substance of the embryo. The endosperm cells at the extreme micropylar end are disorganising as a result of the presence of the fungus, and are also included in the figure.

Stage C.

Text-figure 7 illustrates the external appearance of the ovary when it is approaching maturity. A considerable amount of endosperm has been formed; the shadowed portion of the diagram indicates the extent and distribution of this tissue. As in the two previous stages, the ovary is drawn from the ventral surface. The furrow is noticeable at the proximal end, but as yet, is not well developed at the distal extremity. The dorsal proximal end projects beyond the rest of the ovary in the form of a pocket, in which the embryo develops.

Sections taken at this stage emphasise the facts already disclosed. The great bulk of the nucellus has disappeared, whilst the endosperm has increased in a well-marked and definite manner. The hyphae are still abundant, but owing to their absorption by the endosperm they are not as plentiful as in Stage B. The disorganisation which takes place all round the periphery of this layer keeps the growth of the hyphae in check, and, consequently, they never over-run the developing grain, but tend to decrease in amount after the first appearance of endosperm. (Plate XXIII.) The food-supply made available to the grass by the digestion of the hyphae is utilised by the young actively growing endosperm cells. This is rendered possible, for the growth in size of this tissue takes place from the outer surface. The outermost layer of the endosperm may be regarded as a cambium, which is active only on its inner surface. This meristematic layer divides in the usual manner, and the cells so formed are at first more or less brick-shaped, but gradually assume an approximately spherical form, and attain their adult size. Growth is carried on in this manner until the fruit is practically mature, then this outermost dividing layer ceases its activity, but persists in the grain as the aleurone layer, the cells of which serve as a store of nitrogenous material. This idea of an *endospermic cambium* is supported by the fact that the nuclei of this layer remain large and intact, even when the cells are



Text-Figure 7.

The external appearance of the ovary of *Lolium perenne* at Stage C. × 15 diam.

packed with reserved food, and also the walls of the aleurone cells become thickened, showing pits or points of communication at intervals. It is a well-known fact that cambial cells embarking on a period of rest show considerably thickened cell walls. The thickenings are usually removed wholly or in part, when such a layer recommences its activities.

If the stamens, before they ripen, are removed from a spikelet and cross-pollination is also prevented, the ovary remains small, but the fungus will grow rapidly in the nucellus, and ultimately forms a sclerotial-like mass of hyphae, occupying the main part of the ovule. Freeman records this fact for Darnel, and I have had similar results with English rye grass. Since, by preventing pollination, endosperm formation does not take place, this dense growth is only to be expected, for even in a fertilised ovary the fungus is parasitic on the nucellus, and for a short period tends to increase in amount. The prohibiting factor is the endosperm, which destroys the hyphae as fast, or faster, than they are being formed, hence removal or absence of this factor favours the development of the fungal organism, and the attempt towards sclerote formation is the result.

The primary tissues have been cut off in the embryo. It has elongated considerably in length at the expense of the endosperm cells adjacent to it. (Plate XXV., Fig. 3). These no longer form a close investment to the embryo, but have disappeared at the micropylar end, and the embryo now lies free in the embryo-sac. The attachment of the suspensor to the microple is broken at this stage. Hyphae still run in close association with the embryo, and in section it shows the hyphae running in its tissues.

Transition from Stage C to the Mature Grain.

Externally, the only changes which are evident during this transition are the elongation of the ovary, accompanied by an increase in breadth, and the development of the embryonic area, which becomes more pronounced as the scutellum develops and the embryo reaches maturity.

Sections taken at any stage during this period show features common to the earlier stages. The increase of endosperm, resulting from the continued activity of its outer layer, tends to crush the hyphae, which are ramifying in the remnants of the nucellus, into a layer running round the periphery of the seed. This layer becomes more pronounced as the endosperm reaches its adult size, and fills

the space formerly occupied by the nucellus, the outer parts of which are the last to disappear. Starch cells continue to be formed until the seed is almost ripe, and the hyphae nourish these young starch cells, just as they did the inner, now mature, starch cells, in the younger stages already described.

When the endosperm attains its full size, the outer dividing layer ceases to function, and becomes the young aleurone layer. The cells, which constitute it, retain their embryonic form, as regards both their size and shape, in their adult condition. They eventually thicken their walls considerably, and their contents become packed with aleurone grains, so that finally the nitrogenous layer characteristic of the endosperm of cereals is formed.

Plate XXIV. illustrates a section of the endosperm taken at the stigmatic end of a grain, at a stage when the aleurone layer is not yet adult. The hyphae, which by this time are in the form of a layer, take part in the nourishment of the aleurone cells. Just, as in the case of the starch cells, they actually enter into the cell cavity by penetrating the cell-wall, and become absorbed by the protoplasm which converts the nourishment so obtained into the aleurone grains which are present in great abundance in the adult layer. This plate shows several hyphae passing through the walls and disappearing into the cell-contents.

The aleurone cells figured are young. They show a well-marked nucleus, and are filled with protoplasm, in the meshes of which aleurone grains are being formed. The absorption of the hyphae continues until the cells are packed with grains, and the seed is nearly ready for ripening. A section of a fully mature normal endosperm shows, however, no signs of the endophytic nature of the fungus.

It is interesting to note that Peklo (16) suggested that the aleurone layer was probably fungal in origin in all cereals. The suggestion arose as a result of an incidental examination of some *Lolium temulentum* grains. In order to carry the investigation further he decided to examine grains of *Triticum*, *Secale*, and *Hordeum*. He recognised the necessity of examining rust-resistant types, and stated fully in his paper the varieties he proposed to examine. With the forms chosen he obtained negative results. Not deterred, he next examined material he already had embedded in paraffin, but he did not state its origin, or given any information regarding its rust-resistant capacities.

Examination of such material revealed fungal hyphae occupying the lumen of the aleurone cells, from which densely stained bodies were budded off. Peklo believed them to be aleurone grains. It seems highly probable that the grains used for sectioning were mouldy, and that the aleurone grains figured are in the process of digestion. This is accentuated by the fact that some grains were found actually embedded in the hyphae themselves, and also by the fact that Peklo suggests that the fungal threads found bear a resemblance to those of *Mucor Rouxianus* (*Amylomyces Rouxii*), although the actual identity of the two was not established. The point of interest as far as this paper is concerned lies in the fact that Peklo probably found the fungus in the aleurone cells of young *Lolium temulentum* grains, and from this isolated case he attempted to generalise, stating that such was the origin of the layer for all cereals.

The breadth of the hyphal layer found in the grain is dependent on two factors—

(a) The activity of the fungus,

(b) The absorbing power of the endosperm.

If the fungus is strong and luxuriant in its growth, and can keep pace with the activity of the endosperm, a thick hyphal layer would result, for even at maturity the endosperm will not have used, as food-material for itself, all the available hyphae.

If, however, the growth of the mycelium is inclined to be weak, the absorbing power of the endosperm will be greater than the growing power of the fungus, and the result will be a very small layer in the mature grain, or even perhaps the complete absence of such a layer.

In the earlier part of this paper (p. 256) I emphasised the fact that absence of the fungus in hand-sections, or in any individual microtome section could not be taken as evidence of the total absence of the fungus in the grain. The reason for this statement should now be clear. The presence or absence of a definite layer in the grain is dependent on the activity of the fungus, and the absorbing power of the endosperm. Even if a grain does not exhibit a definite layer, hyphae may still be present in the embryo in sufficient amount to ensure the appearance of the fungus in quantity at the desired stage in the development of the next generation of Lolium.

We are also in a position to discuss the significance of the distribution of the fungus in the grain. Freeman attributed it mainly to the result of the method of infection of the embryo, but I

am led to the conclusion that it is a result of the part played by the fungus during the development of its host. The grass so controls and subjugates the mycelium during the changes which take place after fertilisation, that the embryo-sac, as its increases in size, pushes the fungus closer and closer to the periphery, until the mature condition is reached. Not only is the hyphal layer found between the endosperm and the testa, but, if the fungus is active, remnants may be found all round the periphery of the embryonic area, in fact, in any position occupied by them during the later embryological stages. (Plate XVIII. Figs. 1-5.)

The embryo during this period follows the usual course of development. At Stage C it was an undifferentiated club-shaped body, and hyphae were in close association with its micropylar end.

The next marked period of growth results in the appearance of the stem apex (Plate XXV., Fig. 4.) This is followed by differentiation of the radicle and elongation of the cotyledon. When all the parts of the embryo are thus marked off from one another, growth continues until the embryo is fully developed. The fungus, in the meantime, can generally be seen at both the micropylar end, and also, between the developing scutellum and endosperm. It is generally pronounced in the region of the plerome cells of the cotyledon.

Further investigations of the development of the embryo have been commenced in order to determine more exactly the relation of the fungus to its later development, as it is possible that the fungus plays a role in the formation of the scutellum comparable to the one it plays in the formation of the endosperm.

The hyphae, already in the very young embryo, follow the development of the stem-apex, and remain localised in their growth until germination takes place.

The Fungus in the Plant.

The growth of the fungus keeps pace with that of the plant, the hyphae, however, are mainly restricted to the growing apex, but can be seen extending for a short distance down the stem. They show the dual staining property already described (pg.

Even at this stage the intra-cellular nature of the fungus can be demonstrated. Some of the parenchymatous cells of the grass are invaded, and used as a food supply by the hyphae. Such cells always stain with gentian violet, and they show a dense network of

hyphae. They may occur near the vascular tissue, and also towards the periphery of the stem,

When the inflorescence is formed, they are especially abundant at the base of the carpels. The cells so affected do not increase in size, and are only to be distinguished from a normal unaffected cell by their different staining properties. It is not till the ovule is well advanced that any great increase in the fungal partner takes place, when the phenomena already detailed follow in their natural sequence.

Cultivation of the Fungus in Artificial Media.

All attempts by previous workers to obtain a pure culture of the fungus have been unsuccessful. Their work has been limited mainly to the nucellar hyphae. So far I have been no more successful than Nestler and Freeman in endeavouring to get the fungus to grow outside its host. As further work is being done in this direction, it has been thought advisable to give a short account of the methods employed and the results so far gained.

Since hyphae isolated from the hyphal layer of the grain had not yielded any result, and as they represent the dormant stage of the fungus, I thought greater success might be attained if the cultures were made from a more active stage in its life-history. Accordingly, the ovary was thought to be a suitable starting point, and stages ranging from A-C in the development of the grass have been used for infecting the culture media.

For the most part the culture medium has been made up in the following way :—

A decoction of *Lolium perenne* in water was autoclaved, then filtered and cleared with egg albumen. The liquid so obtained was made into a 1% agar solution, and autoclaved. It was subsequently filtered, titrated, tubed and sterilised.

Other media have been tried, e.g., honey agar, starch agar, etc., but with no better results.

The ovaries were treated in various ways, before using them for infecting the plates.

(1) Some were washed for one minute in equal parts of a 1% mercuric chloride solution and 45% alcohol, followed by a thorough washing in sterile distilled water.

(2) Others were washed in ether for varying lengths of time, from five minutes to one minute.

(3) Others, again, were shaken for some time in sterile distilled water.

After this preliminary treatment they were crushed with sterile forceps and introduced into the mouth of the agar tube, and then immediately plated. A drop of lactic acid solution being introduced to eliminate the growth of bacteria.

(Crushing the ovaries brings the fungal hyphae into direct contact with the medium used, and it was though that this might induce growth).

Some of the plates were left at room temperature, others were incubated at 23°-25°C. As a rule the plates were found to remain remarkably free from external contamination, and exhibited no growth at all. Occasionally some superficial fungus, mostly *Penicillium*, developed from the surface of the ovary, more especialy from the stigmas.

Probably the preliminary treatment to which the ovaries were subjected may have acted detrimentally on the fungus, even killing it. Further work, however, requires to be done to decide this point.

One plate infected with an ovary, which had previously been immersed in ether for four minutes, exhibited a fungal growth which seemed to arise from the ovary as a centre and which could not be attributed to any of the commoner superficial forms.

The first signs of growth appeared on the third day after infection. The hyphae were extremely septate, and their tips seemed to divide into two, the resulting branches growing equally. At this time there were no signs of spore formation. On the thirteenth day signs of fruiting bodies were noticed. When young they appeared salmon pink in colour, becoming very dark when old. They were irregular in size and shape. and appeared to be of the nature of pycnidia.

I have to thank Mr. C. C. Brittlebank (Government Plant Pathologist) for identifying the growth so obtained. He had no hesitation in placing it as a *Coniothyrium*, probably closely related to *C. olivaceum*, Bon. The ovary from which the felt was obtained was fixed, along with a portion of the felt, in Fleming's weak solution, and afterwards microtomed. The sections showed that the tissues of the ovary remained intact during the growth of the mycelium, and hyphae similar to those composing the felt were found running in its tissues.

This may or may not be the fungus found in the *Loliums*, but its close affinity to *Phoma* is rather suggestive, for many mycorrhizal forms have been found to belong to this latter genus.

The ovary used in this plate was obtained from a plant growing in the Melbourne University grounds. It was apparently the product of a second flowering resulting from heavy early autumn rains. Since all attempts to obtain this form again have been unsuccessful, it might be argued that it cannot be the fungus found associated with *Lolium perenne.* This may be so, but it is just probable that since the ovary represented a second flowering the fungus may be growing more actively than the developing grain, the grass being naturally weakened by its previous flowering, so that the fungus may have been in a suitable condition to grow on the artificial medium provided.

Concerning the Function of the Fungus.

It has been suggested that the fungus associated with Darnel grass possesses the power of nitrogen-fixation. Hiltner (5) was the first to formulate this idea, and after testing it by experiment, he concluded that *Lolium temulentum* grew as well in nitrogen-free sand, as in sand to which nitrogen, in the form of potassium nitrate, had been added as a fertiliser. As a control he grew *Lolium italicum* under similar conditions. This species, at the time of Hiltner's work (1899), was regarded as being fungus free. Later, Freeman (1903) found in a sample of 59 grains two contained the fungus and 57 were devoid of it. This, although it is a low percentage of infected grains, could introduce a serious error into such work when using this species as a control.

The experimental methods employed by Hiltner are also open to criticism. He planted grains of both species in pots, which were completely nitrogen-free, but he watered one set of two with tap-water, which contained 0.84 mg. of nitrogen per litre. To the other set of two he gave in addition 50 mg. of nitrogen in the form of potassium nitrate. These pots were apparently left exposed to the air, and so were subject to many sources of external nitrogen contamination, the most formidable perhaps being nitrogen-fixing bacteria.

An experiment carried out in this manner could not aim at determining whether the fungus is capable of fixing free atmospheric nitrogen in *the compelete absence of combined nitrogen.* However, as several investigators have shown, Berthelot (17), Puriewitsch (18), and Latham (19), that certain fungi can fix free nitrogen if supplied with a small amount of this element in a combined form, the results given by Hiltner might have some bearing on the latter point.

The following figures are extracted from his paper :—

I.—*Without nitrogen manure.*

	Dry Weight gr.	Nitrogen absolute mg.	Nitrogen per cent.
Lolium temulentum	5.173	30.35	0.59
Lolium italicum	0.974	6.69	0.69
Root mixture	3.619	7.78	0.22
Total	9.766gr.	44.82mg	0.46%

II.—*Manured with 50 mg. of nitrogen.*

	Dry Weight gr.	Nitrogen absolute mg.	Nitrogen per cent.
Lolium temulentum	5.867	72.87	1.24
Lolium italicum	2.329	40.70	1.75
Root mixture	3.381	12.60	0.37
Total	11.577gr.	126.17mg.	1.09%

The nitrogen content of *Lolium temulentum* plants, when fertilised with potassium nitrate, is seen by the above figures to increase markedly as compared with that obtained for unfertilised plants, i.e., plants watered with tap water only. Not only is this so, but the increase is nearly as great as that obtained for *Lolium italicum*. The small difference between the percentage results for both species is not outside the limit of experimental error, especially when the sources of such error are as great as in the experiment in question.

Rayner (20) when dealing with the symbiotic relation of an associated fungus in *Calluna vulgaris*, refers to the case of Darnel grass, and says: "Some degree of symbiosis has been inferred, but the experiments of Hiltner to establish nitrogen fixation for this fungus are inconclusive."

In describing the distribution of the fungus (a peculiar mycorrhizal form) found in *Calluna vulgaris*, Rayner draws attention to the fact that in many points it resembles the fungus in Darnel. The fungus from *Calluna* was isolated and grown in pure culture, and was found to be closely related to the genus *Phoma;* nitrogen-fixation was suggested as its function. Duggar and Davis (21) showed that *Phoma Betae*, when grown on mangel or sugar beet decoction, produced a nitrogen gain of from 3.022—7.752 mg., pointing definitely to nitrogen fixation for this particular fungal species. In fact, it was the only definite positive result obtained from all the forms experimented with.

Although many mycorrhizal fungi are thought to aid their host plant in this way, considerable uncertainty exists concerning the determination of the species producing mycorrhiza and their actual function.

These facts suggest that it is not improbable that the fungus associated with Darnel or English rye grass might act as a nitrogen-fixer, so an experiment was devised to try and establish a definite answer to this suggestion as regards *Lolium perenne.*

Materials and Apparatus.

(1) Method of Preparing Sand.

Sand cultures were chosen, as they supply a rather more natural condition for the plant roots than water cultures, and sand has the additional advantage of being practically insoluble, and it does not interact with the nutritive compounds used in the watering solutions. In order to obtain it free from all traces of nitrogen, it was subjected to the treatment recommended by Schramm (22). A good sample of fine quartz sand was chosen. This was thoroughly washed for about two hours in running tap-water. It was next boiled in strong hydrochloric acid for about one hour, and then washed with distilled water until chlorides could no longer be detected on the addition of silver nitrate. The sand was then heated to a red heat in a furnace for eight hours. This effectively removes any organic material which may be present. The ash formed in this way and any remaining traces of nitrogen were removed by a second boiling in pure strong hydrochloric acid. A second washing with distilled water ensued, and was carried on until the sand was free from chlorides. Finally it was washed a dozen times with nitrogen free water, and then dried in a drying oven. After this treatment, on testing for ammonia, nitrites and nitrates, only negative results were obtained.[5]

5. Nessler's reagent was used in testing for ammonia. The Lunge test (Diphenylamine) was used in testing for nitric acid. A modification of the Peter-Griess method was used in testing for nitrous acid. This test is extremely delicate, according to Anderson (25). One-thousandth of a milligram can be detected with certainty. The Griess-Ilosvay method is as follows:—

(1) Dissolve 0.5 gm. of sulphanilic acid in 150 cc. of 2-normal acetic acid.

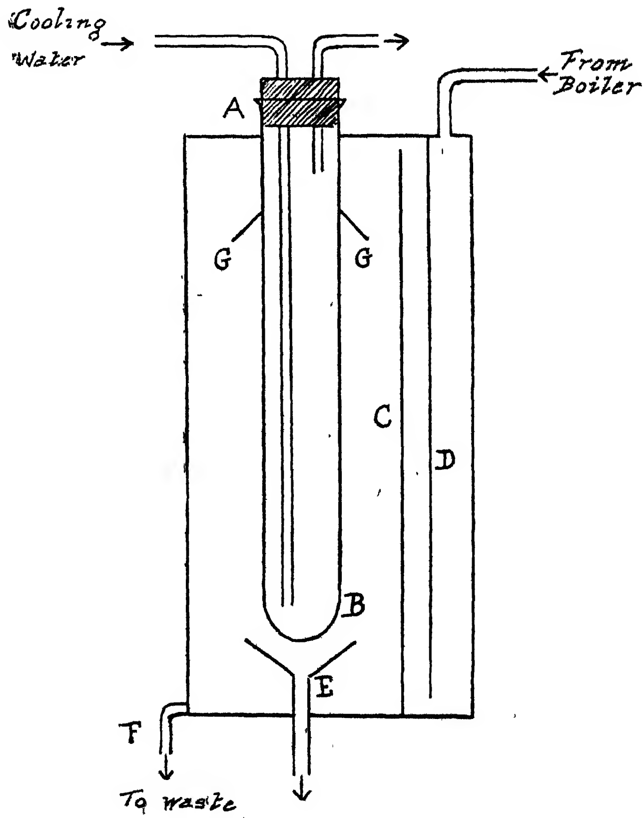
(2) Boil 0.2 gm. of *a* naphythylamine in 20 ccs. of water. Pour off the colourless solution from the violet residue, and add to the solution 150 cc. of 2-normal acetic acid. Mix the two solutions. (This mixture must be kept in a dark place.) Take 50 c.c. of the material to be tested with 2 cc. of above reagent, and allow it to stand 5 or 10 minutes; it will be coloured red if a trace of nitrous acid is present.

In using this test, the flask should be plugged with cotton wool, to prevent dust from entering the solution and disturbing the result.

(2) Low conductivity water.

I have to thank Dr. Rivett, of the Chemistry Department, Melbourne University, for the use of a still, the pattern of which was first described by Hartley, Poole and Campbell (28), and which readily yields water of conductivity as low as 0.4×10^{-6} mhos. The method employed is briefly as follows:—

Ordinary distilled water is boiled for about 10 mins. in a 10 litre copper vessel, open to the air, and this is connected to the apparatus shown in text-figure 8.



Text-Figure 8.

A diagram of the condenser used in preparing low condctivity water, AB = condensing tubs; E = collecting funnel; C and D = Copper sheet baffles; G = tin flap welded to AB to prevent condensate from soldered junction running down A.B.

The essential part is the condensing tubes A B, which is of pure tin. Before the entering steam can reach the condenser, it must travel round two copper-sheet baffles C and D, which effectively retain liquid particles projected from the boiler. The condensate drips into the tin-funnel E, and is collected in a 3-litre Jena glass flask, with the usual guard tubes of soda lime. It is removed from the flask by siphoning. The outer cylinder is of copper, and is protected by asbestos sheeting on the outside. No water which condenses on the cylinder or the copper baffles-plates can enter the funnel E; it is drained away at F. To prevent the condensate running down A B from the soldered junction of the tube with the top of the cylinder, a tin flap is welded on, as shown at G. The drippings from this fall outside the funnel E. The middle fraction of 3 litres is the purest.

Apparatus.

Two large glass shades, fitted into a groove round the periphery of wooden stands, were used for covering the pots, in which the grains were planted. These were carefully cleaned with acid-dichromate cleaning mixture. In each case a long glass tube bent at right angles to itself was inserted through the stand into the cylinder. These were connected in turn to a series of wash-bottles. The first of these contained chemically pure sulphuric acid, giving no nitrogen reactions. This acid bottle was connected to two series of water-wash bottles, one set belonging to each cylinder. The connections were made with glass and rubber tubing. Between the last wash-bottle and each shade, a tube of wider diameter was inserted, containing a germ-proof cotton plug. A second tube of smaller length, also bent at right angles and fitted through the wooden base into the other side of the cylinder functioned as an exit tube. These in turn were connected each to a wash-bottle, and then to a water pump. By this means a slow current of air could be kept drawn through the cylinders. Before reaching them, the air had to pass through the acid, two wash-bottles containing nitrogen-free water, and finally through the cotton plug, so all combined nitrogen in the form of dust, etc., was removed before the air reached the pots. This treatment also reduced to a minimum the chance of nitrogen fixing bacteria, present in the atmosphere, gaining access to the sand.

After the experiment had been running for some little time, it was evident that a large amount of water was being carried over

by the air and condensing on the sides of the glass cylinders. In order to prevent the air from being too moist, U-tubes containing pure calcium chloride were inserted betweeen the last wash-bottle and the cotton plug.

Watering with the nutritive solutions was carried out by a siphon arrangement. A glass tube bent at an angle over each pot was connected by rubber tubing to a separating flask. This was tightly stoppered, and the stopper covered by a small inverted beaker to prevent dust from falling on it. By raising or lowering this flash the solutions flowed freely on to the pots and the quantities given could be altered at will.

The pots themselves had glazed surfaces, and were quite nitrogen free.

Before setting up the experiment, all the glass bottles and tubing were washed with the cleaning mixture, and then several times with nitrogen-free water. The open ends were plugged with cotton wool and sterilised, in a steam steriliser, on three successive days. The rubber stoppers and tubing were boiled in dilute alkali, then in dilute acid, and subsequently washed with nitrogen free water. Connections were made as soon as possible after removing the plugs.

The slot in the stand into which the cylinders fitted was sealed with putty, all the other joints were sealed with paraffin. There was every indication that the connections were air-tight.

The grains before planting were treated with a 2% formalin solution for 8 minutes, then washed thoroughly in nitrogen-free water. By previous trial it was found that this treatment did not affect the germination capacity of the seeds, and rendered them as sterile as possible.

The sand, being prepared in the manner already described, was sterilised, left to cool, moistened with nitrogen-free distilled water, and the grains planted. The shades were immediately fitted into place, the connections made, and the experiment commenced running on August 18th, 1919. It was so arranged that an equal amount of illumination was received by both pots.

The drying tubes soon became saturated with water, and it was found necessary to change them every second day. The U-tubes when not in use were kept sterilised and plugged, so that the sterility of the system was not affected by this factor. The sulphuric acid and water in the wash bottles was also changed occasionally, so as to prevent any traces of nitrogen accumulating in

the last wash bottles, and thereby reaching the cylinders. During the process of changing the bottles, the rubber connections with the cylinders were clamped, so that air could not reach them.

(4) *Nutritive solutions.*

The control pot was watered with a nutritive solution, made up according to the following formula:—

Ammonium nitrate, 0.5 gram.
Potassium di-hydrogen phosphate, 0.2 gram.
Calcium sulphate, 0.1 gram.
Magnesium sulphate, 0.1 gram.
Sodium chloride, 0.1 gram.
Ferric chloride, 0.04 gram.
Nitrogen-free water, 1000 ccs.

The second pot was watered with a similar solution, excluding the ammonium nitrate.

The chemicals used were the purest that could be obtained. The watering solutions when ready for use gave negative results, with the nitrogen tests already described.

Results.

August 18th.—Experiment commenced.

August 27th.—Grains were germinating freely in both pots.

September 15th.—The seedlings in the control pot were taller and were showing a better colour than those deprived of nitrogen.

September 16th.—First signs of yellowing at tips of leaf in nitrogen-free seedlings.

September 19th.—All the seedlings in the nitrogen-free cylinder showed their first leaf distinctly yellow at tip, and the yellow colour was extending back along the edges of the lamina. The seedlings were all in the two leaf stage. The second leaf was quite green. The seedlings in the control cylinder looked very healthy. No signs of discolouration were evident in them.

September 30th.—The nitrogen-free seedlings were about one-third the height of the control seedlings. The first leaf was very much discoloured and withered. The second leaf was still green, showing no signs of yellowing. The third leaf just visible. The control seedlings were healthy, and of a good green colour; they showed 5-6 leaves.

October 13th.—The nitrogen-free seedlings were very unhealthy. The second leaves showed discolouration, and were dying from the tip downwards. Very much behind the control.

October 20th.—The nitrogen-free seedlings were beginning to die out. The control seedlings were exceedingly vigorous and normal.

October 30th.—The experiment was dismantled for photographic purposes, as the remaining nitrogen-free seedlings were failing rapidly.

The phenomena noted during the course of the experiment are typically those resulting from nitrogen starvation. The yellowing of the older leaves always commencing at the tip indicates that these members are being sacrificed in order that any nitrogen they possess (i.e., nitrogen obtained from the seed) may be made available for transference to the young developing leaves. This transference of nitrogen from the first-formed leaves to the actively growing centre enables the plant to exist for a certain period of time, but the lack of nitrogen manifests itself in the stunted growth and unhealthy colour and appearance of the plants.

It may be concluded from this experiment that no power of nitrogen-fixation in the absence of external supplies of combined nitrogen can be ascribed to the endophytic fungus of *Lolium perenne.*

Conclusion.

It is difficult to decide what is the actual relationship between the fungus and the Lolium plant. It could, perhaps, be regarded as a case of symbiosis, the fungus helping in the plant economy during the formation of the grain. In return for this it is housed by the grass, and its propagation is ensured by the admittance of hyphae to the embryo, so that it is able to appear in each successive generation without the intervention of a spore stage. It can only be a matter of conjecture whether this stage is entirely lost to the fungus or whether it is repressed, only as long as conditions are favourable to its transmission in the usual way, but still retains the power of sporing if in danger of extermination. The sporing stage may occur under such conditions, but up to the present it has not been recognised as belonging to the fungus normally found associated with at least two species of Lolium.

As opposed to this conjecture, Freeman (26), although he had not demonstrated the intra-cellular nature of the fungus, advocated

the view that it was a smut. He was drawn to this conclusion by the idea "of the probable progression of the evolution of parasitism in smuts," from the loose smut of oats through the loose smut of wheat to the Lolium fungus. The loose smut of wheat, forming as it were, an intermediate stage between the loose smut of oat and the fungus of Lolium. It is well known that the spores of the loose smut of wheat infect the ovary at the flowering stage, and there form a mycelium, which perennates in the embryo of the grain, growing when it germinates in the manner of most smuts, and forming its spores during the next flowering stage.

The Lolium fungus could be regarded as a development from a type such as this, in which the sporing stage has been entirely suppressed, or at most occurs extremely rarely.

The points in the life-history of the fungus associated with *Lolium perenne*, which could be used to support this view, are:—

1. The behaviour of the hyphae during the growth of the plant up to the flowering stage, which closely resembles the method adopted by the *Ustilagineae*.
2. The formation of knots in the tissue of the young ovary, which, however, I prefer to explain, not as an attempt towards spore-formation, but as the preliminary to cell infection.
3. The intra-cellular course of the hyphae.

These, at first sight, undoubtedly seem to weigh heavily as evidence in favour of its relation to the smut family, the most suggestive being the behaviour of the fungus during the vegetative period of the grass.

This mode of growth in the host plant, however, is not limited to the *Ustilagineae*. Rayner (20) describes a fungus associated with *Calluna vulgaris* which grows in the tissues of the plant without any external evidence of its presence or without disturbing the normal growth of the host.

The greatest development of the fungus in this case takes place on the roots of the plants forming a mycorrhiza, endotrophic in character, but unlike most other mycorrhizal plants, the fungus keeps pace with the growing point of the stem, and after the inception of the ovary it enters this organ, and forms a mycelium in the ovary wall. The embryo remains sterile, but infection of the seed-coat is accomplished by the hyphae, so that the production of a mycorrhiza in the roots of the next generation of Calluna is not left to chance

The fungus in the seed-coat becomes active on germination, infects the seedling, and produces the felt on the root; indeed the association is so close that the symbiosis is an obligative one, the seedlings not developing unless infected.

This is a very striking instance of symbiotic association, and, as Rayner points out, the only other plant for which a like distribution of the fungus has been described, is *Lolium temulentum.* Since I have demonstrated the intra-cellular nature of the Lolium fungus it falls even more in line with the Calluna type. Although it does not form a mycorrhiza, its use to the plant is certainly demonstrated at the fruiting period. It is possible, therefore, to regard it as a case parallel to the Calluna type, the similarity to the Ustilagine mode of growth being accidental, and not of any real importance in helping us to classify it and to grasp its affinities. Since the Calluna fungus has yielded to artificial culture, and can be classed definitely as a *Phoma*, every hope can be entertained for success in this direction as regards the fungus of the Loliums.

The occasional penetrations of the endosperm, etc., already described, do not, I think, point to vestigial traces of a former parasitic habit. Even when present they do not evince any harmful results in the grain. They are probably to be explained as a luxuriant development of the fungus, resulting perhaps from good growth conditions. The endosperm has proved unable to cope with the large food-supply represented by the fungus, and consequently has failed to transform it all into the usual storage form—starch and aleurone grains, so that some of the hyphae which had penetrated the tissues of the embryo, and would normally have been absorbed, remained intact. Any food-material they contained would be yielded up on germination, just as the food-material of the endosperm is changed into soluble forms, and translocated to the seat of growth.

Although I have never examined a grain of *Lolium perenne* either mature or in an embryonic condition without finding the fungus present (sometimes in minute amounts), it is quite probable that such occur.

It is conceivable that the hyphae, when growing in the young inflorescence may miss a carpel and in that case the ovule would not become infected. This would probably not prevent the formation of a fruit. The grain so formed, however, would not be so well equipped in its struggle for existence as its fungal-containing neighbour, and eventually would tend to die out. It is, therefore,

unlikely that two races of both *Lolium temulentum* and *Lolium perenne* exist, one with a symbiont, the other fungus free. An occasional grain of either species may show the absence of hyphae, but this would be accidental in character, so that instead of an ever-increasing number of the latter type, they would always tend to remain at a more or less stationary minimum.

Summary.

The foregoing investigation has led to the following results :—

(1) The occurrence of the fungus in the genus *Lolium* is wider and more constant than has hitherto been demonstrated.

(2) Colour of the grain cannot be regarded as a diagnostic character in regard to the presence or absence of the fungus.

(3) The fungus is intra-cellular or endophytic in nature.

(4) The distribution in the grain is not a result of any special method of infection, but is a result of the function of the fungus during the grain's development.

(5) It is present in the embryo-sac at or immediately after fertilisation.

(6) The fungus increases in quantity at the expense of the nucellus, and the cells of the carpel wall. This is only a temporary phase. On the formation of endosperm the fungus is absorbed as a source of food-supply to the developing embryo.

(7) The endosperm is formed by the division of its outer layer. This layer functions as a kind of cambium. I have termed it the *endospermic cambium.* The cells which are cut off always to the inner side, increase in size, remain thin-walled, and become packed with starch. This outer meristematic layer is constantly receiving and absorbing hyphae, which, if present in any quantity, are finally crushed into a layer around the periphery of the endosperm. If the fungus does not keep pace with the absorbing power of the endosperm, no hyphal layer is formed in the ripe grain, but hyphae can then be found in the scutellum and embryo.

(8) The endospermic cambium after it has ceased to divide persists as the aleurone layer, which, in turn, receives a supply of nutriment from the fungal system.

(9) The ovum is infected before any divisions have taken place in it.

(10) The hyphae aggregate at the proximal end of the developing grain. They are here used by the endospermic cells in the embryonic pocket for food-supply for the developing embryo.

(11) The association of the fungus with *Lolium temulentum* and *Lolium perenne* is probably a well-marked case of symbiosis, comparable in many respects with that met with in *Calluna vulgaris.*

(12) It has been suggested that nitrogen fixation was the function of the fungus, but an experiment has been performed, and the result obtained showed that the fungus of *Lolium perenne* is unable to fix nitrogen in the total absence of external supplies of combined nitrogen.

The foregoing work was carried out in the Botanical Department of the Melbourne University during the years 1917, 1918, and 1919. I have to thank Professor Seward, Cambridge; Mr. S. F. Armstrong, Agricultural School, Cambridge; Dr. Stoward, Western Australia; Mr. Burtt Davey, South Africa; Mr. Breakwell, Sydney; Vilmorin-Andrieux and Cie, Paris; and the Royal Botanic Gardens, Kew, for forwarding supplies of grain from different parts of the world; also Mr. O'Brien, Assistant in the Botanical Department, Melbourne University, for the help he has afforded in assisting with experiments and taking photographs. To Professor Ewart I am indebted for the facilities provided for the work, and for much helpful criticism during its progress.

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EXPLANATION OF PLATES.

All figures have been drawn with the aid of the camera lucida (Zeiss).

Plate XVIII.

Figures 1-5 stained with aniline gentian violet, followed by Gram's iodine wash. They illustrate the distribution of the fungus in the grain, the position of the hyphae is indicated by the yellow line shown in the figures.

Fig. 1.—A semi-diagrammatic representation of a transverse section through the distal part of a grain of *Lolium perenne*.

(a) aleurone layer; (b) cells of aleurone layer, which stain differently from the rest, probably ferment-containing cells; (e) starchy endosperm; (h) hyphal layer; (h^1) coloured portions of hyphae (the great bulk of the layer is not stained with the gentian violet); (t) pericarp and testa.

Fig. 2.—A transverse section of the proximal end of the same grain. Letters as in Fig. 1, and (s) scutellum; (el) epithelial layer of scutellum.

Fig. 3.—A transverse section of the extreme proximal end of the grain. Letters as before, and (r) radicle; (ht) hyphae in fused pericarp and testa.

Fig. 4.—A longitudinal section of a grain of *Lolium perenne* taken in the coronal plane. Letters as in Figs. 1-3, and (g) growing point of embryo; (l) sheathing leaf.

Fig. 5.—A longitudinal section of a grain of *Lolium perenne* taken in the sagittal plane. (m) embryo; (v) vascular bundle of scutellum; (i) ligule; (ht) hyphae in fused pericarp and testa.

Plate XIX.

The following figures have been drawn from sections of a grain of *Lolium perenne* (South Africa). The fungus is especially luxuriant, its intra-cellular nature being evident in the mature grain.

Fig. 1.—A sagittal longitudinal section of a grain of *Lolium perenne*, not passing through the median line. The scutellum shows numerous hyphae, which have gained entrance to this tissue from any point on its surface.

(e) starchy endosperm; (a) aleurone layer; (el) epithelial layer; (h) hyphae in scutellum; (h^1) hyphae round periphery of the scutellum; (c) cells invaded by the hyphae. ×250 diam.

Fig. 2.—Detail of the scutellum.

(h) hyphae passing through the scutellar cells; (c) constriction of hypha during penetration of cell wall. ×1700 diam.

Fig. 3.—Aleurone cells, showing the intra-cellular course of the hyphae,

(a) aleurone cells; (w) wall of aleurone cell; (h) hypha passing from one cell to the next; (h^1) hypha lying at a different level, but drawn in the same plane in figure. ×1700 diam.

Fig. 4.—Detail of scutellum, showing the cells invaded by hyphae. ×1100 diam.

Fig. 5.—Wall of aleurone cell, showing hypha entering into cell through pit in its wall

(p) pit in wall; (h) hypha. ×1100 diam.

Plate XX.

A longitudinal section of an ovary of *Lolium perenne*, just prior to fertilisation; stained with bismarck brown, then with gentian violet, followed by Gram's wash.

(c) carpel wall; (s) starch groups in cells of carpel wall; (i) invaded cells at stalk end of section; (h) hyphae in stalk of ovary; (h^1) hyphae in distal part of wall; (h″) hyphae in distal part of wall not staining with gentian violet; (t) cells in stigmatic tract being used by the fungus as food; (ov) ovule; (hy) hyphae distributed in all parts of ovule; (ic) infected cells of ovule; (es) embryo-sac; (o) ovum; (hy^1) hyphae in embryo sac. × 103 diam.

Plate XXI.

Figures 1-6 show detail of ovule illustrated in Plate XX. (Stage A).

Fig. 1.—Three cells of nucellus, showing the intra-cellular nature of the fungus. These cells react to the violet stain, the rest of the nucellus staining with bismarck brown.

(n) nucleus; (h) hyphae; (h^1) fine ramifications of hyphae in the cells. × 1100 diam.

Fig. 2.—A cell from the carpel wall which is being attacked by the fungus and used as food-material for the fungal system.

(h) hyphae running between the cells; (h^1) fine penetrating threads; (g) starch grains being digested by hyphae; (s) septum in hyphae. × 1100 diam.

Fig. 3.—"Knots" formed by the hyphae wrapping round the cells as a preliminary to their entrance into them. The lightly-shaded portions are lying at a lower level than the darker sections of the hyphae. × 1100 diam.

Fig. 4.—A vascular element from the stalk end of the carpel wall, showing the close association of the fungus.

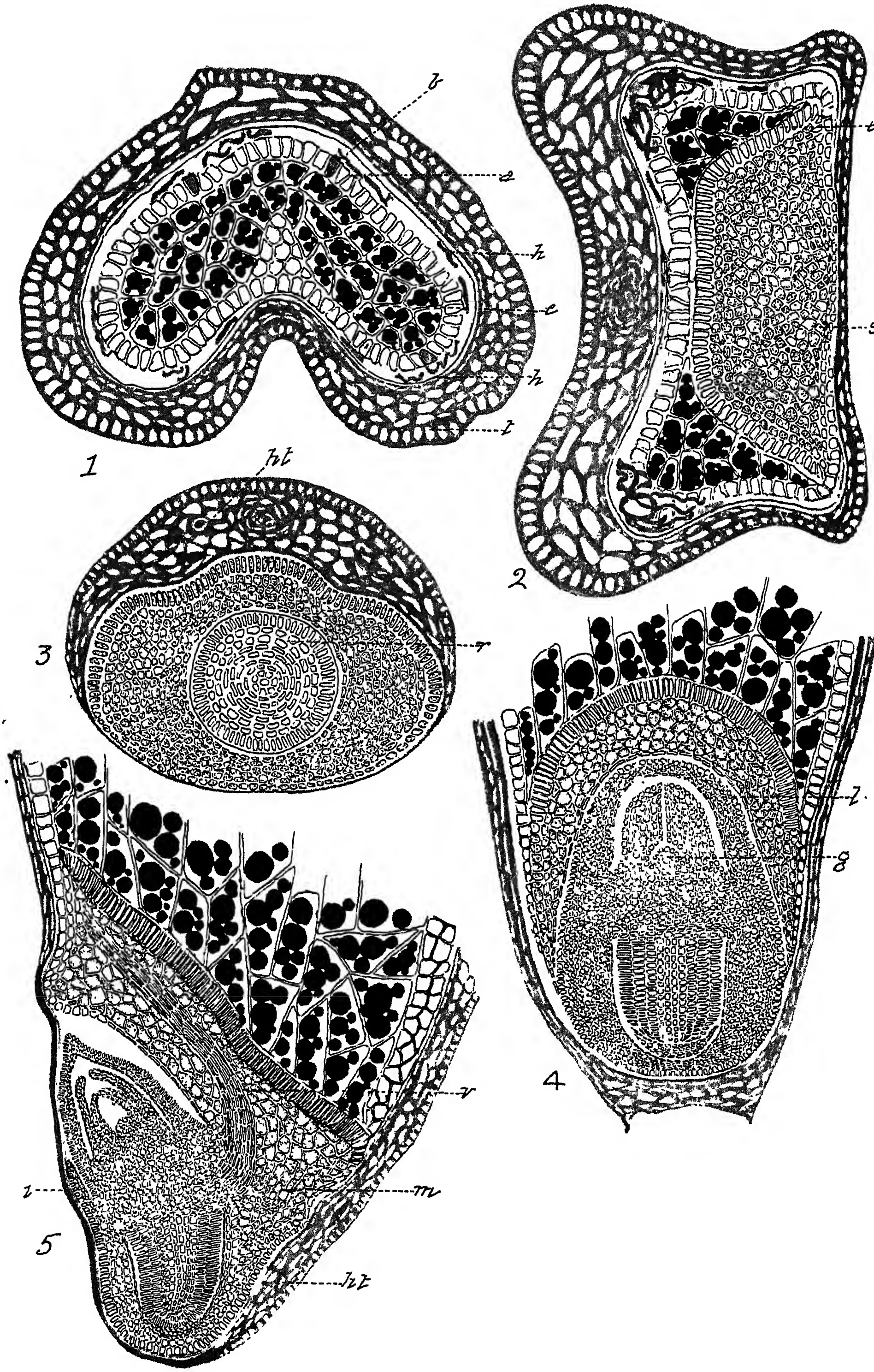
(r) thickenings on vessel; (h) hyphae. × 1100 diam.

Fig. 5.—Cells from the distal end of the carpel wall.

(g) starch groups; (h) large intra-cellular hyphae; (h^1) fine hyphal threads completely wrapping round grains prior to digesting them. × 1100 diam.

Fig. 6.—Ovum and synergidae; showing presence of hyphae in ovum before any divisions have occurred in it.

(o) ovum; (s) synergidae; (n) nucleus (nuc) nucellus; (h) hyphae. × 700 diam.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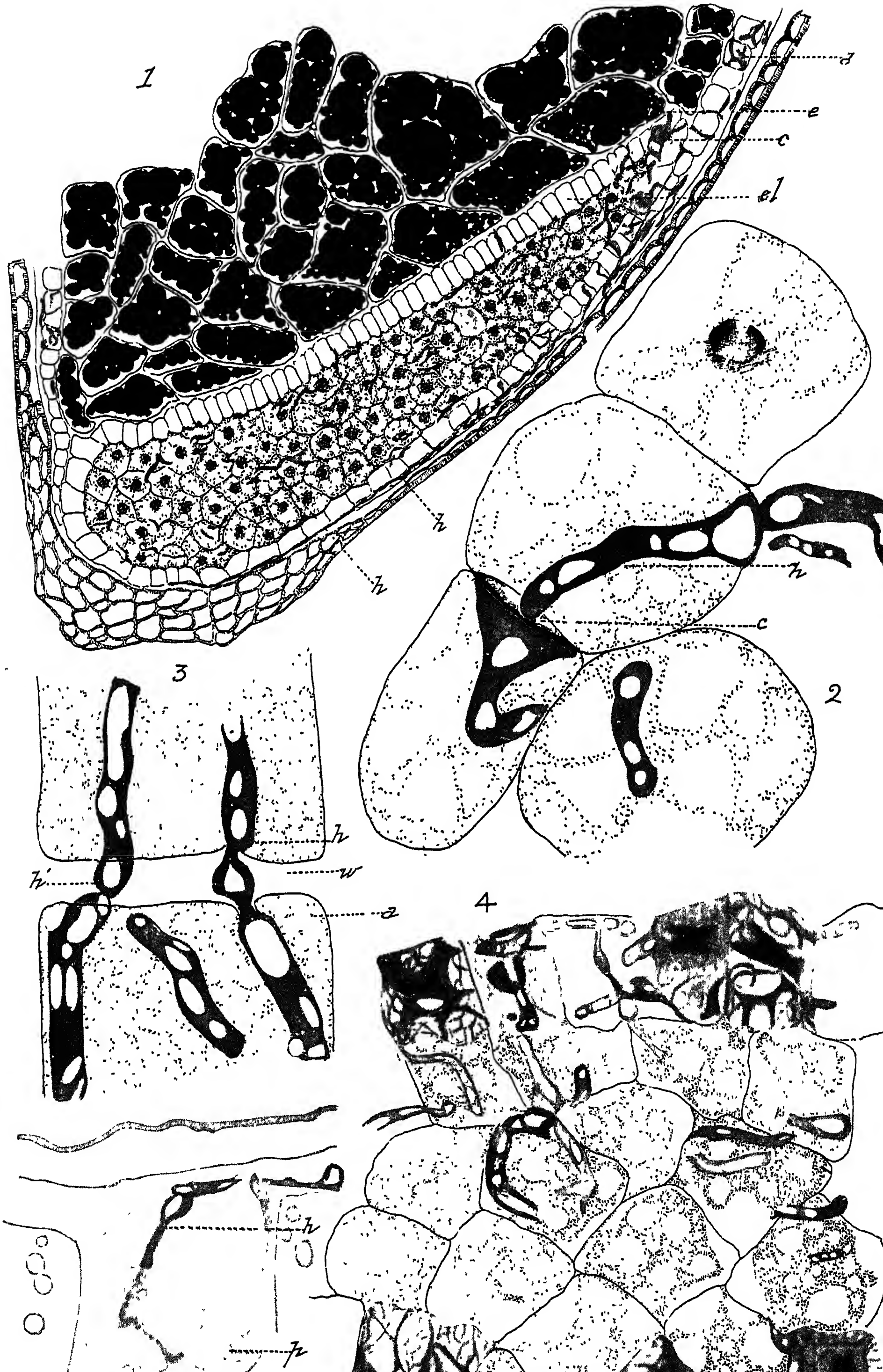
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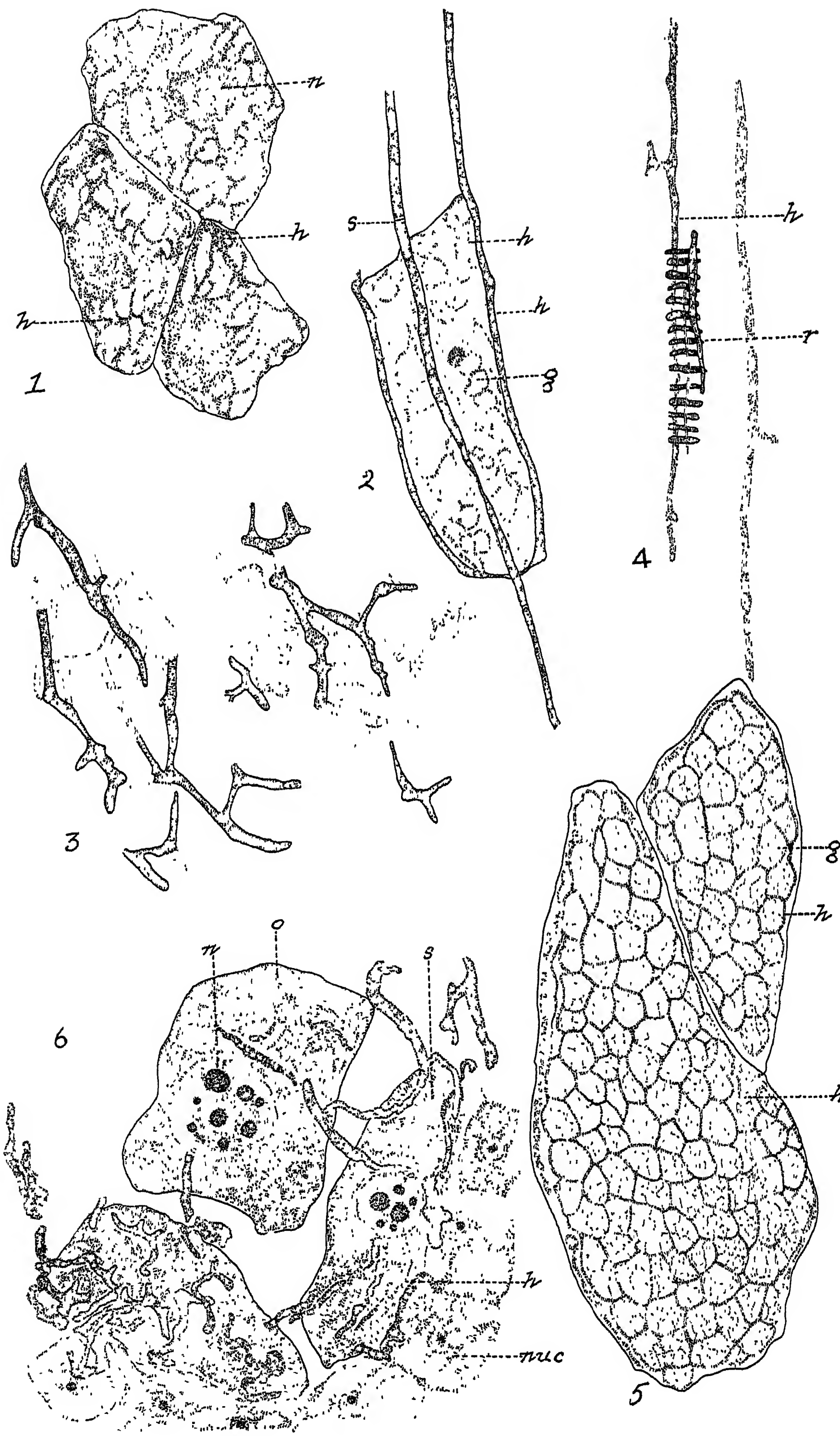
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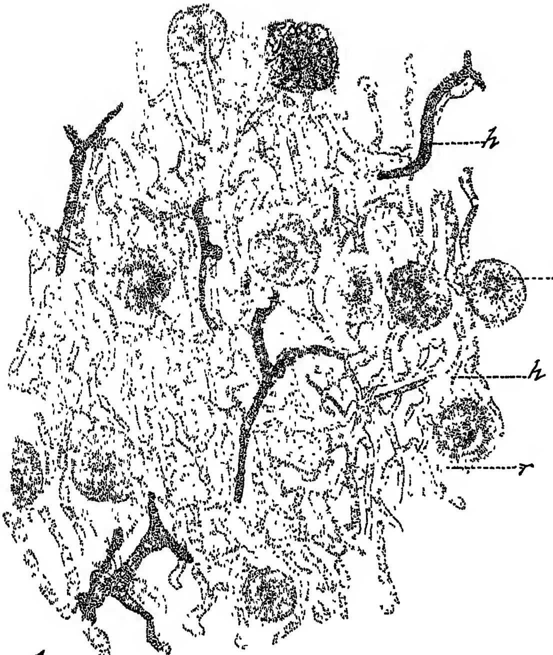

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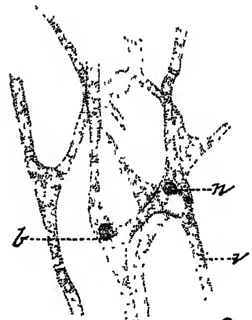

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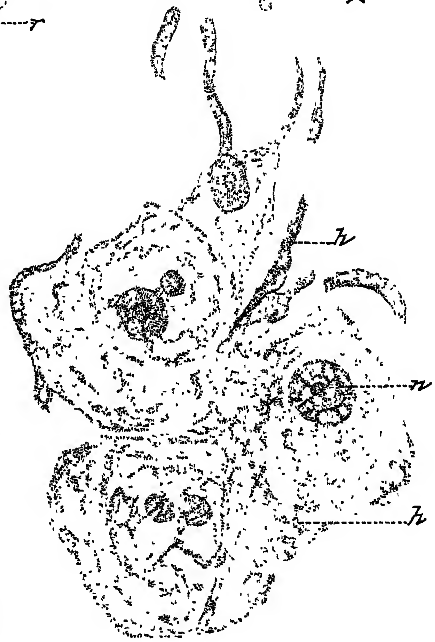

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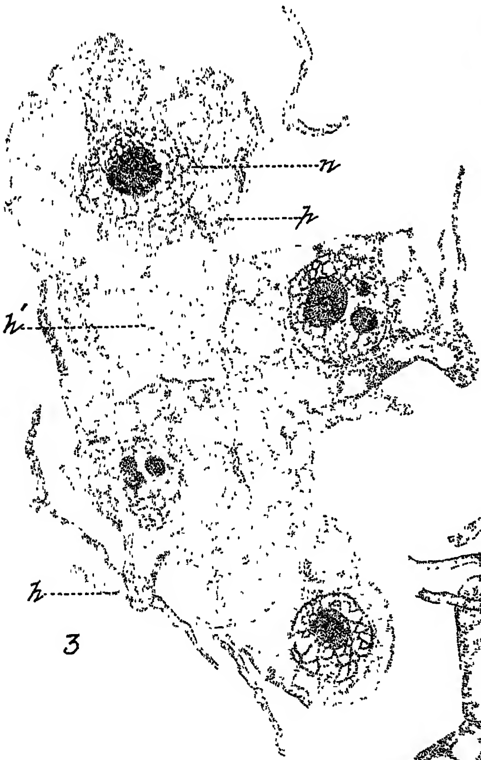

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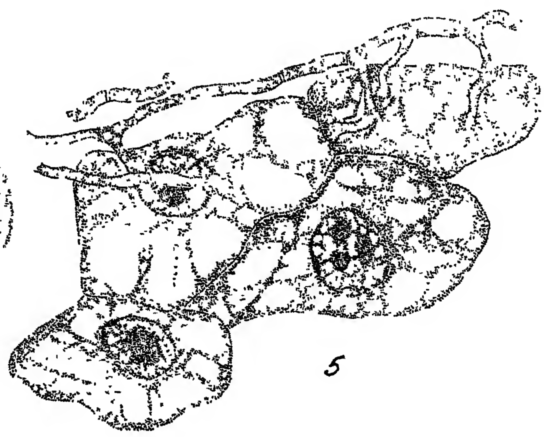

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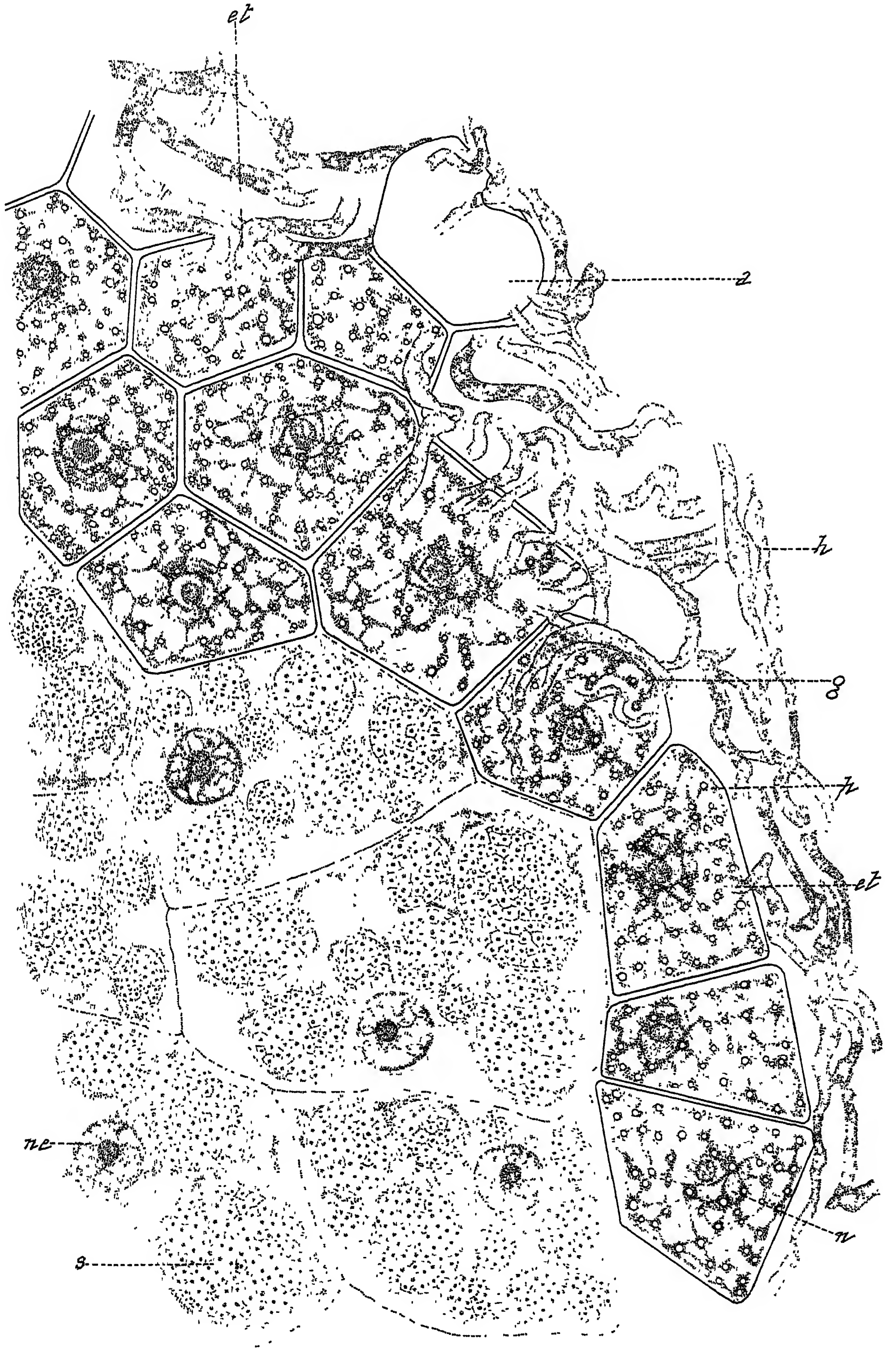
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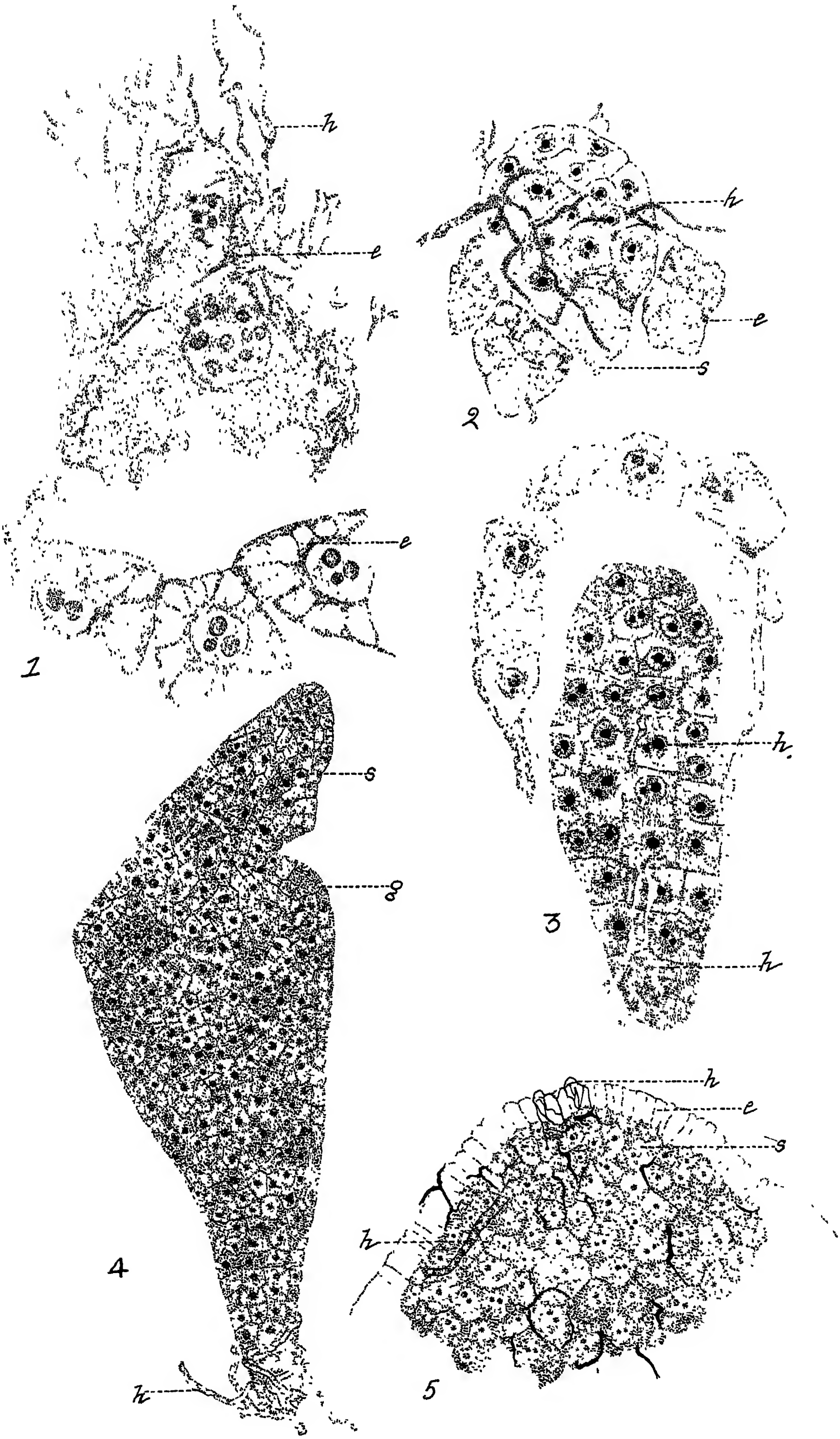
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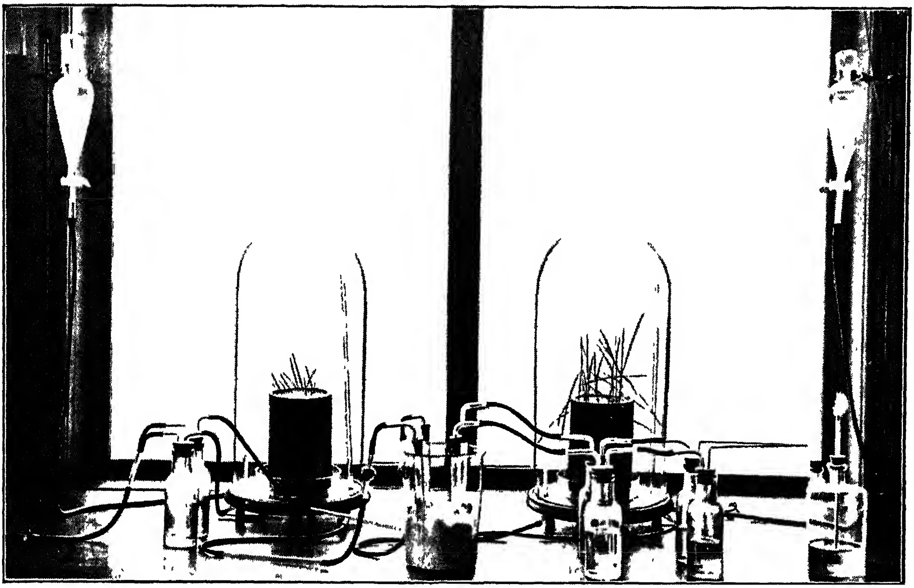
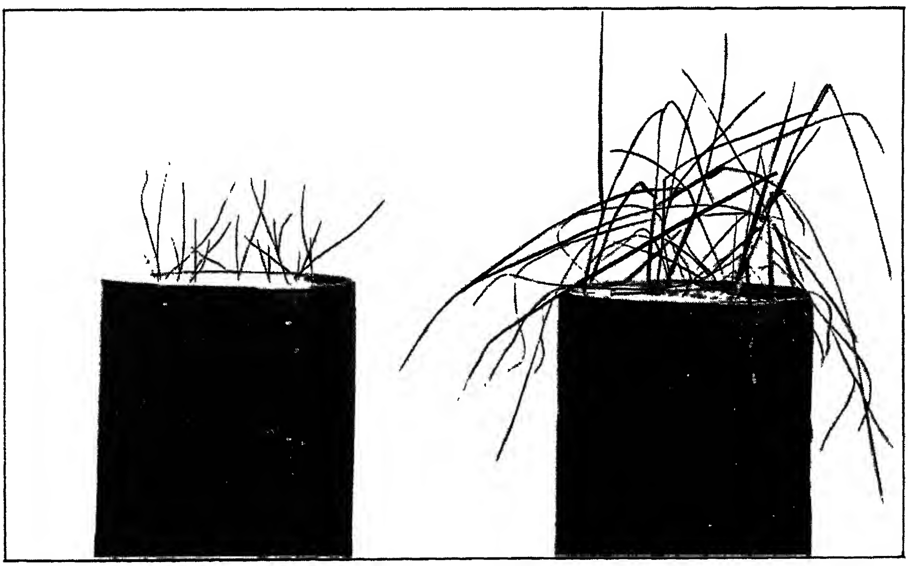


Fig. I.



A Fig. II. B

Plate XXII.

Illustrates detail of ovary at Stage B. The sections were stained with congo red, followed by gentian violet and Gram's iodine wash.

Fig. 1.—Detail of nucellus, showing network of hyphae.

(n) disorganising nuclei; (h) hyphae stained with congo red; (h^1) hyphae stained with gentian violet; (r) remnants of protoplasm of nucellar cells. × 1100 diam.

Fig. 2.—Mode of branching of hyphae in nucellus.

(n) nucleus; (v) vacuole; (b) origin of branch. × 1100 diam.

Fig. 3.—Young endosperm cells showing the hyphal threads entering and being absorbed by them.

(n) nucleus of endosperm cell; (p) protoplasm of endosperm cell; (h) hyphae; (h^1) hyphae in process of absorption. × 1100 diam.

Fig. 4.—Similar to Fig. 3, but section taken from another grain and stained only with gentian violet. The protoplasm remained unstained and the hyphae in the cells stained brightly with the violet dye.

(n) nucleus of endosperm cell; (h) hyphae entering cell; (h^1) hyphae in protoplasm of endosperm cell in process of absorption. × 1100 diam.

Fig. 5.—Same as 3 and 4, but shows the branches arising almost at right angles to main hyphal thread, and entering the endosperm cells. Lettering as before. × 1100 diam.

Plate XXIII.

A section of the endosperm taken from a grain at Stage C. It was stained with congo red, gentian violet and Gram's iodine. The outer edge of this tissue is included in the figure. The cells in this area are young, and more or less cubical, being formed by the division of the outermost layer; starch has not yet appeared in them. The older cells of the endosperm are large, and thin-walled, and starch is being deposited in the protoplasmic network. Hyphae are being absorbed by the outer dividing layer, and serve as a source of food-supply to the endosperm.

(h) nucellar hyphae; (h^1) hyphae being used by the endosperm as food; (c) young dividing layer; (e) older endosperm cells; (s) starch groups; (p) protoplasm. × 1100 diam.

Plate XXIV.

A portion of the endosperm from a nearly mature grain. The outer layer is being transformed into the aleurone layer, but even at this stage hyphae are entering the cells, and are being absorbed by them. The aleurone layer is cut tangentially in the upper part of the grain; the layer therefore, appears several cells thick at this point. The starchy endosperm cells immediately underneath the nitrogenous containing cells show well-marked nuclei, but these will disappear as the grain reaches maturity.

(a) aleurone layer; (g) young aleurone grain; (p) protoplasmic network in aleurone cells; (h) hyphae accumulating to form a layer; (et) hyphae entering aleurone cells; (n) nuclei of aleurone layer; (s) starch groups; (ne) nuclei of endosperm cells. × 1100 diam.

Plate XXV.

Figs. 1-5 illustrate the relation of the fungus and embryo at different stages in the development of the grain.

Fig. 1.—Endosperm cells from the embryonic pocket drawn from the same slide as Fig. 2. The fungus occurs in great abundance in this region at this stage. It is being used by the endosperm, which in turn hands on the food material to the embryo.

(h) hyphae; (e) endosperm cells of embryonic pocket; (e^1) ordinary endosperm cells. × 625 diam.

Fig. 2.—A young embryo.

(e) endosperm cells being used by the embryo as food; (h) hyphae; (s) suspensor end of embryo. × 625 diam.

Fig. 3.—An older embryo, the endosperm cells at the proximal end of the pocket have disappeared.

(h) hyphae present in embryo. × 625 diam.

Fig. 4.—An embryo showing differentiation of scutellum, and growing point. Stained densely with congo red, so that hyphae in growing point could not be seen.

(h) hyphae at suspensor end; (g) growing pt.; (s) scutellum. × 300 diam.

Fig. 5.—The tip of the scutellum from a grain of *Lolium perenne* (not yet fully developed), which did not contain an extra cellular hyphal layer in the usual position. Hyphae were present, however, in the scutellum and embryo.

(s) scutellum; (e) epithelial layer; (h) hyphae. × 500 diam.

PLATE XXVI

Fig. 1.—A photograph of the appaiatus used in the experiment desciibed in the paper

Fig. 2.—The two pots removed from the protecting shades at end of experiment.

(A) Seedlings watered with a culture solution containing ammonium nitrate.

(B) Seedlings deprived of combined nitrogen, except such as is stored in the seed. The stunted growth is evident, but the photograph does not shew the unhealthy colour and dying back exhibited by the seedlings, and which is so characteristic of nitro gen starvation

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XIX.—*On the Structure of a New Species of Earthworm from South Australia, Megascolex fletcheri.*

By JEAN H. SHANNON, B.Sc.

(Communicated by Professor Sir Baldwin Spencer).

[Read December 11th, 1919].

(With Plates XXVII.-XXXI.)

Up to the present time, though a large number of species of earthworms has been described from Australia, more especially by Dr. Michaelsen,[1] from South-West Australia, Prof. Spencer,[2] and Mr. J. J. Fletcher,[3] from New South Wales, Victoria, Queensland and Tasmania, there has, as yet, been published only one more or less complete detailed account of one type of Australian earthworm—Megascolides australis. The species now described represents another type, differing in important respects from Megascolides, and, on the suggestion of Professor Sir Baldwin Spencer, I have attempted to describe its structure as completely as possible. The work has been carried on in the Zoological Department of the Melbourne University.

I have followed the classification suggested by Michaelsen.[4] The species evidently belongs to the genus Megascolex, as defined by him, and I propose for it the name of *Megascolex fletcheri*, the specific name having reference to the first naturalist who made a study of Australian earthworms.

Habit.

The material dealt with in this paper was collected in South Australia at a spot about ten miles due east from Kapunda, the latter being a town situated in an agricultural district.

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1. Michaelsen.—"Die Fauna Südwest-Australiens," erster Bund, 1907-1908, pp, 117-232.

2. Spencer.—"The Anatomy of Megascolides australis." Trans. Roy. Soc. Vic., Vol. I., Part I., 1882. "Preliminary Notice of Tasmanian Earthworm," op. cit. 1894.

3. Fletcher.—A series of six papers, the first of which, "Notes on Australian Earthworms, Part I.," was published in Proc. Linn. Soc., Vol. I., Series 2, 1886, p. 523. The remaining five were published in the same Proceedings in 1886, 1887, 1889, respectively.

4. Michaelsen.—op. cit. p. 160.

The type of country is gently undulating, and mostly very rich clayey soil. The timbered land is isolated now, owing to cultivation.

The climate is moderate, with occasional very dry seasons, and generally a long summer with high temperatures.

These particular earthworms seem to be very peculiar and restricted in their habitat. Quite a large area of scrub land was very carefully searched, and only two small spots were found to shelter the worms. One was a somewhat low-lying, damp place beside a dam, and the other a more or less elevated spot, less timbered and sunny. In both cases the earth worms were concealed underneath cut timber for fence posts, and during the wet winter of last year were very plentiful.

Their habits were essentially moisture loving, and in the damp earth, and even in the actual timber distinct, and large holes or burrows were made, down which the worms rapidly disappeared when the post was overturned. A considerable amount of slimy, glassy material was found wherever the worms had passed, and the earth all about their burrows was well worked and divided. In some cases only a furrow was made in the earth, the lower surface of the post serving to roof it in.

When the specimens were dropped into spirit for preservation, they definitely contracted, and, as is usual with earthworms, put out a large quantity of slimy fluid through the dorsal pores all along the body.

External Anatomy.

The freshly collected worms are of a pale pink colour, and vary somewhat in size, but as a rule are from ten to twelve inches in length, and between one quarter and a-half an inch in diameter.

The clitellum is very distinct in the mature animals, and is of a paler shade than the rest of the body. It is situated about an inch from the anterior end, and is not quite regularly cylindrical, being pinched in on the ventral surface. It extends from just after the eleventh segment to the end of the eighteenth. The surface of the worm appears to be covered by a translucent and very thin membrane, but in the spirit specimens the glassy appearance is lost to a large extent, and the membrane becomes rather more conspicuous and tougher, but looses its iridescence.

There is a ring of stetae in the middle of each segment, broken at the mid-dorsal and mid-ventral lines. The most median pair on the ventral surface on each side are somewhat larger than the rest.

The segments themselves are quite distinctly marked, especially in the spirit specimens. There is a distinct median furrow around each segment, and towards the anterior end of the worm two smaller furrows may generally be found, one on either side of the main furrow.

The prostomium is normally very nearly completely dove-tailed into the peristominum.

The openings to the exterior of the dorsal pores and of the reproductive organs are mostly quite distinct, and can be seen with the naked eye.

On the dorsal surface the only openings that occur are the dorsal pores. These are situated between the successive segments in the median line, the first being between segments four and five.

On the ventral surface the most conspicuous openings are those of the vasa deferentia, on the eighteenth segment. Each is surrounded by two swollen somewhat semi-circular lips, is situated away from the median line between the third and fourth pairs of setae, and is not included in the clitellar region. (Plate XXVIII. Fig. 1. ♂) (Plate XXVII. Fig. 1. ♂).

On the fourteenth segment ventrally is a single median raised oval area, and in the centre of this is the opening of the common duct formed by the union of the right and left oviducts. (Plates XXVI1 and XXVII., Fig. 1 ♂).

Between segments six and seven, seven and eight, and eight and nine, are the three pairs of spermathecal pores, opening ventrally. It is very difficult to decide whether they open in line with the fourth or the fifth seta.

In one fresh specimen that I examined there seemed to be an indication of two smaller openings, on either side of the main pore. Subsequent dissection showed the presence of accessory glands in this region in all instances.

Besides these more conspicuous openings there are certain small glands associated with the spermiducal gland, and communicating with the exterior on the ventral surface between segments sixteen and seventeen, nineteen and twenty, twenty and twenty-one, and twenty-one and twenty-two.

Internal Anatomy.

Alimentary Canal.—The living worm has very marked power of evaginating the whole crop to the extent very often of one-quarter of an inch. Upon opening up the worm one finds that the front

end of the gizzard is invaginated, and appears almost urn-shaped, until the front end is pulled out, when it becomes oval.

The posterior end of the gizzard is between segments six and seven, and all the septa up to this region are considerably displaced, forming angles of about 22.5° with the body wall.

The anterior end of the gizzard is very changeable, according to the amount of evagination it has undergone.

Following on from the gizzard is a long, almost straight intestine running the length of the body, and opening to the exterior at the posterior end. It presents a bulbous expansion in each segment along its length. (Plate XXVII. Fig. 2.)

Nervous System.

There is a distinct nerve collar around the oesophageal region in segment two, with a conspicuously swollen dorsal portion slightly pinched in at the median line. On either side of the collar is given off a large nerve, which runs forwards to supply the anterior part of the oesophagus. A smaller branch supplies the crop behind on each side. After the union of the nerve ring ventrally, the fibres are collected into a very conspicuous cord, which is slightly swollen in each segment. A transverse section of the cord reveals the rather a-typical fact that there is only one large giant fibre present. (Plate XXVII. Fig 3.) (Plate XXX. Fig. 2.)

Nephridial System.

From dissection there does not appear to be a nephridial system other than very numerous micronephridia forming a fringed ring around each segment, especially towards the posterior end.

Microscopic examination of longitudinal sections taken from about the last third of the worm, reveals very peculiar structures, possibly represent a special form of nephridial organ. They are perfectly regular in position, and segmentally arranged. Each is somewhat club-shaped, and attached to the wall of the coelome by a thin stalk. Even under the very high powered objective, there appears to be little structure. The stalk is made up of almost a single chain of nucleated cells, which gradually merge into those of the outer peritoneum. They appear to have no duct, and no passage is visible from them through the muscle layers to the exterior.

The head portion of the structure has different forms, sometimes being long and regular, with a covering of small nucleated cells,

and an internal longitudinal clear region, that may, perhaps, indicate the presence of a minute duct. Along the latter at intervals are rounded patches of very numerous and clearly nucleated cells. The rest of the structure seems to be almost non-cellular. Sometimes the base of the "head" is distinctly broadened, and a number of parallel ducts appear to traverse it. In yet other cases the central duct seems to follow a spiral course. In one instance the end of the structure appeared to bend towards an opening through the septum, thus seeming to indicate a relationship to the successive segments typical of meganephridia. (Plate XXIX. Fig. 4.)

The supposition that these organs are connected with the excretary function is further borne out by the development as seen in very young specimens. At an early stage the whole structure is hardly more than a chain of cells, with large nuclei, and at intervals clusters of even more regular and oblong cells. An arrangement that suggests the nephridial structure in some species of Megascolides figured by Beddard, page 51, fig. 13.

The marked similarities between this worm and certain of the Megascolides types again strengthens the idea that the mega nephridia which are generally well developed in the latter genus, are represented in this animal by the peculiar structures described above. Besides this, the position of the organs at the posterior end, their segmental arrangement, and their structure also bears out the theory as to their function.

Blood Vascular System.

This system is very difficult to study, except in freshly killed specimens. Extending along the mid-dorsal line of the main length of the body is a large thin-walled dorsal vessel. Smaller lateral vessels are given off on each side in segments five, two and nine.

Just ventral to this vessel is a much smaller median one, extending between segments eight and fourteen.

A large thin-walled pair of hearts spring from either side of this vessel by a very small connection in segments ten, eleven, twelve and thirteen. A very fine pair of vessels also spring from this longitudinal vessel in each segment just anterior to the hearts, and probably are present in segments eight, nine and fourteen as well. (Plate XXVII. Fig. 2.)

There seems to be only a single median ventral vessel into which open the large hearts, but just before doing so each heart gives

off a very fine vessel from the outer side, supplying the body wall. Microscopic examination of this ventral blood vessel in transverse section showed that the thickness and structure of the walls were quite peculiar. (Plate XXX. Fig. 4.)

There is a quite definite endothelial lining, with large nucleated cells, and a wall that seems to be largely composed of muscular fibres, running mainly in a circular direction. Besides these elements there are numerous very large clear nucleated cells in the walls of the vessel, and here and there between these latter are quite conspicuous spaces or holes.

Reproductive System.

Female Organs.—The paired ovaries are situated in the thirteenth segment and the two oviducts have very large funnel-shaped openings just below them. The ducts pass through the septum, dividing segments thirteen and fourteen, and then pass to the mid-ventral line, and unite as they pass through the thick muscular wall to open to the exterior. The interior of each oviduct and of the common duct is richly supplied with long cilia, the length of which seems to be about equal to the radius of the passage. (Plate XXVII. Fig. 3.) (Plate XXX. Figs. 1, 2, 3.)

Male Organs.—There are two pairs of testes, one in each of segments ten and eleven. These are peculiarly small, even in a well-matured specimen. The vasa deferentia correspond in number with the testes, and open by very conspicuous and much folded rosettes just below the testes, and then continue quite separately and slightly embedded in the ventral muscles of the body wall to the eighteenth segment. Here, still paired, they enter the muscular wall of the duct from the spermiducal gland of their own side, about the middle of its length, and run parallel with the lumen for some little distance before they enter separately.

The structure and relation of these separate vasa deferentia recalls that of the same parts in Megascolides australis. (Plate XXVII. Fig. 3.) (Plate XXXI. Figs, 1, 2, 3.) Plate XXVIII. Figs. 5, 9.)

The spermathecae are paired and situated in the seventh, eighth and ninth segments, decreasing in size from behind forwards. Each consists of an oval sac, with an equally long but finger-like diverticulum, arising from just below the junction of the base of the sac with its stalk. In the most mature worms this process often appeared to have become lobed at the tip. (Plate XXVIII.

Fig. 3.) The spermathecal sac and its diverticulum open to the exterior by a large duct through the stalk. In the last region this passage seems to be furrowed transversely. (Plate XXIX. Fig 1.)

Associated with the spermathecae are other paired glandular structures. In the sixth segment is found the first pair one on each side. The seventh and eigth each contain two pairs and in the ninth is again a single pair. Ducts from these glands open on either side of the ducts from the spermathecae—i.e., between segments six and seven, seven and eight, and eight and nine. (Plate XXVII. Fig. 3.) (Plate XXVIII. Fig. 2.) (Plate XXIX. Fig. 1.)

The minute structure of these glands is very difficult to determine. Each is decidedly floccular in nature, and the surface cells are large, nucleated, and more or less regular. Internally the cells become less granular, smaller and very irregular, but some still possess very large nuclei, converging to the base of the structure there appears to be clear channel-like spaces between the cells, and these open to the interior of the "stalk." There is no definite duct running from the cell mass, but the whole of the stalk appears to become split longitudinally in an irregular and complex manner. Finally we get a widening of the passage to form a very conspicuous flask-like opening to the exterior. The surrounding epidermal cells become greatly elongated and bow-shaped to surround this structure. In most cases the cuticle is not ruptured, and this seems to show that an opening is formed only at intervals, as the duct becomes full of secretion. Plate III., Figs. 2, 3.)

The vesiculae seminales are large, and occupy most of segments eleven and twelve.

In the eighteenth segment lying tranversely are found two very large organs, the spermiducal glands. Each is flattened dorsoventrally, and is an elongated oval shape. Passing from the inner end of each is a very stout duct, which is practically coiled upon itself on its way to the exterior. The vasa deferentia enter this duct separately about mid-way along its upper surface. The prostate itself seems to be made up of lobes in close apposition to one another.

Microscopic examination shows little definite structure other than the clusters of cells in a less dense matrix, and transverse sections reveal the fact that the whole gland is traversed by one large duct lined by conspicuously nucleated and very regular cells.

In segments seventeen, nineteen, twenty, twenty-one and twenty-two, there are additional glandular structures associated with which are even smaller glands. The detailed structure of these masses of cells is difficult to determine, but apparently each consists of a large number of very granulated, irregularly-shaped and large cells, collected together. Here and there are smaller and non-granular cells arranged in groups.

There does not appear to be a definite duct, but passing from the grandular swelling are numerous small darker cells arranged in clusters, and these follow a disjointed passage through the thick muscular wall.

Problematic Gland in the Thirteenth Segment.

Still another peculiar structure is to be found from dissection, although no indication of its presence is given upon external examination. Attached to the anterior septum of segment thirteen, somewhat ventrally, is a pair of club-shaped organs, each slightly smaller than the smallest spermathecea.

In the less matured specimens examined there were three pairs of these glands—one in each of segments thirteen, twelve and eleven.

At this early stage there is practically no development of the reproductive system, and this fact seems to render it difficult to state definitely, whether these organs are or are not connected with reproduction, From longitudinal and transverse sections of the whole structure there appears to be no definite duct. The most striking features about the organ is the very abundant blood supply, the presence of definitely radiating groups of elements, and the occurrence of numerous spaces in the interior.

Beyond these points, there seems to be little else to notice, and it is difficult to suggest what is the function of these organs.

In conclusion, I wish to thank both Professor Sir Baldwin Spencer and Doctor Georgina Sweet for their valuable assistance and many helpful suggestions during the progress of my work.

EXPLANATION OF REFERENCE LETTERS.

Acc. Glds. - - - -	Accessory glands.
Acc. Op. - - - -	Opening of accessory glands.
Bld. - - - - -	Blood.
B.V. - - - - -	Blood vessel.
B.W. - - - - -	Body wall.

C.	Cuticle.
C. & C_2	Cell and $Cell_2$.
Clit.	Clitellum.
C.M.	Circular muscle.
C. Op. O.D.	Common opening of oviduct.
C. Ovd.	Common oviduct.
Cr.	Crop.
D.	Duct.
D.B.V.	Dorsal blood vessel.
Div.	Diverticulum.
D. of Sp.	Duct of spermiducal gland.
D.P.	Dorsal pore.
E.	Epidermis.
F.G.	Opening to oviduct.
G.	Giant fibre.
G.C.	Granular cell.
Gb.	Goblet, or slime cell.
Gld.	Gland.
Gz.	Gizzard.
H.	Heart.
I.	Intestine.
Inv.	Invaginated gizzard.
K.	Nucleus.
L.M.	Longitudinal muscle.
M.	Tissue supporting V.B. vessel.
N.	Nerve cord.
N.C.	Nerve collar.
Op.	Opening.
Op. Gld.	Opening of gland.
Op. Ovd.	Opening of oviduct.
Op. P.	Opening of spermiducal gland.
Op. S.	Opening of spermatheca.
Ov.	Ovary.
Ovd.	Oviduct.
P.	Peritoneal cells.
Peri	Peristomium.
P. Gld.	Problematic gland.
Pr.	Spermiducal gland.
Pro.	Prostomium.
Ps.	Tissue supporting nerve cord.
Px.	Smaller less granular cells.

R. - - - - -	Rosettes of vasa deferentia.
Rng. - - - - -	Median furrow in segment.
Rs. - - - - -	Large nucleated cells on surface of possible nephridial organs.
S. - - - - -	Setae.
Sac. - - - - -	Sac of spermatheca.
S.C. - - - - -	Spinal cord.
Sept. - - - - -	Septum.
Sg. - - - - -	Large granular cell.
Sk. - - - - -	Sickle-shaped cells.
Spth. - - - - -	Spermatheca.
Spth. Op. - - - -	Opening of spermatheca.
St. - - - - -	Stalk part of gland.
T. - - - - -	Testes.
Vas. D. - - - -	Vasa deferentia.
V.B.V. - - - -	Ventral blood vessel.
V.D. op. P.D. - - -	Vas deferens opening into duct from spermiducal gland.
V.D. - - - - -	Vas deferens.
V. Sem. - - - -	Vesicula seminalis.
X.H.P. - - - -	Position of region shown in Fig 4, under the high powered objective.
X.S. - - - - -	Radiating cells.
X.T. - - - - -	Glandular structure on segment nine (as found in one specimen examined).
Y. - - - - -	Apparent duct.
Y.C. - - - - -	Space between cells.
Y.N. - - - - -	Possible opening of supposed nephridal structure into adjacent segment.
Y.Z. - - - - -	Interior of stalk from accessory gland in segment six, splitting to form apparent duct.

EXPLANATION OF PLATES.

Plate XXVII.

Fig. 1.—Anterior end of earthworm, to show external features (diagramatic).

Fig. 2.—Diagram of anterior end of worm, to show alimentary canal and dorsal blood vessels.

Fig. 3.—Diagram of anterior end of worm, to show reproductive organs, nervous system, and accessory glands.

Plate XXVIII.

Fig. 1.—Anterior end of worm, ventral view, to show main external features.

Fig. 2.—Diagram of longitudinal section through region of spermathecae.

Fig. 3.—Types of spermathecae.

Fig. 4.—Diagram of segment thirteen, to show relative position of associated parts.

Fig. 5.—Sketch of spermiducal gland of right side, to show general features.

Fig. 6.—Drawing of longitudinal horizontal section of problematic gland, in thirteenth segment under the low-powered objective.

Fig. 7.—Part of problematic gland from thirteenth segment, under the high-powered objective.

Fig. 8.—Tranverse section of the spermiducal gland, to show main duct.

Fig. 9.—Diagram of longitudinal vertical section of spermiducal gland, to show mode of entrance of the vasa deferentia.

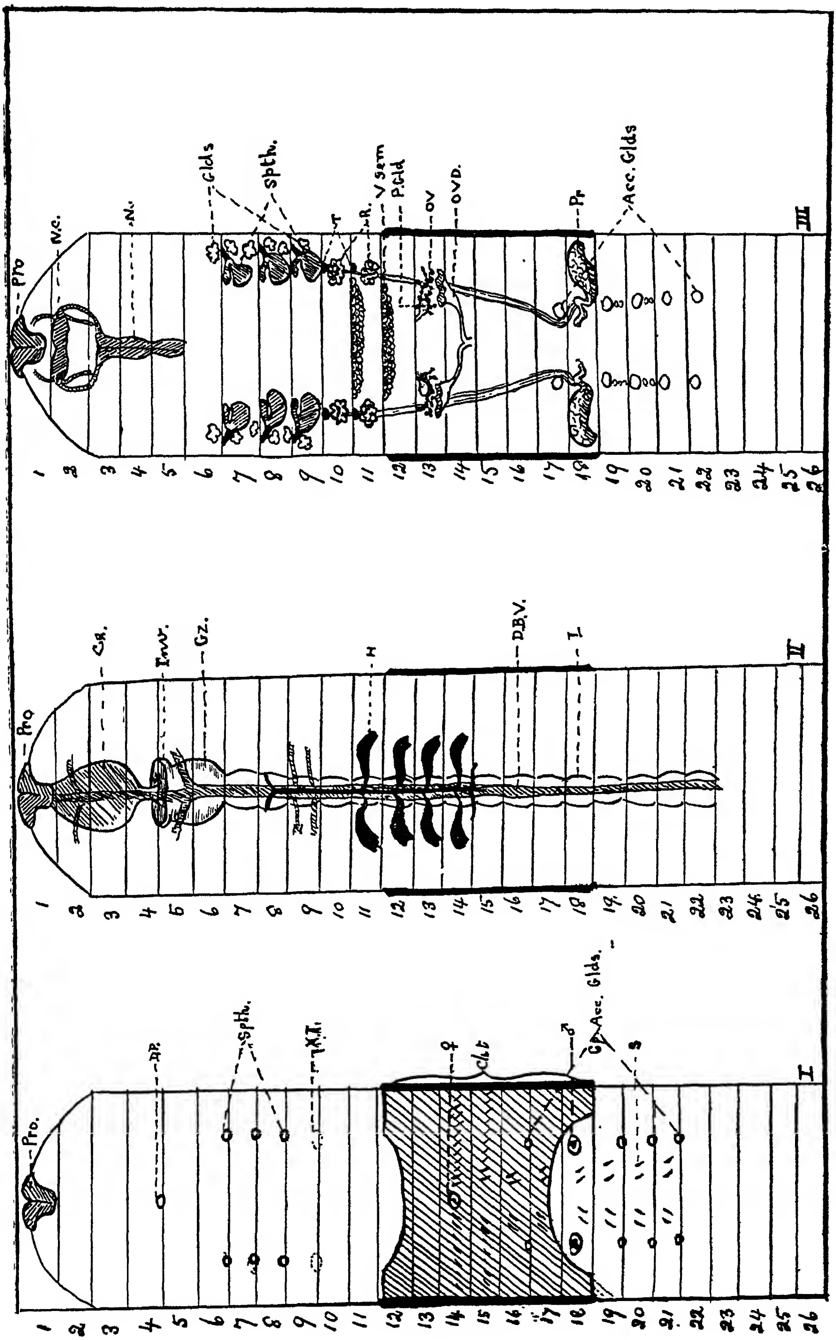
Plate XXIX.

Fig. 1.—Longitudinal section of spermathecal region.

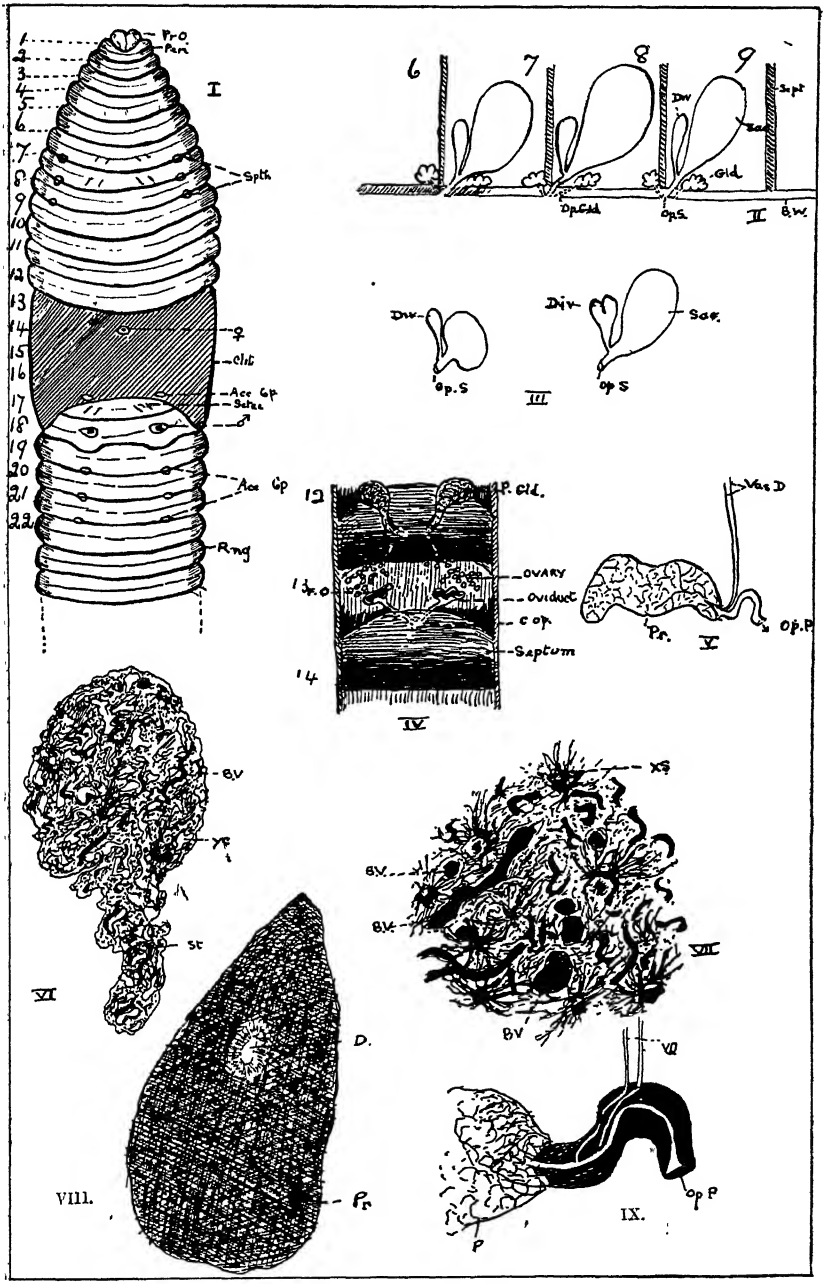
Fig. 2.—Drawing under the high-powered objective of the last part of the duct from a glandular structure associated with the spermathecae.

Fig. 3.—Drawing under the high-powered objective of a section through one of the glandular structures associated with the spermatheeae.

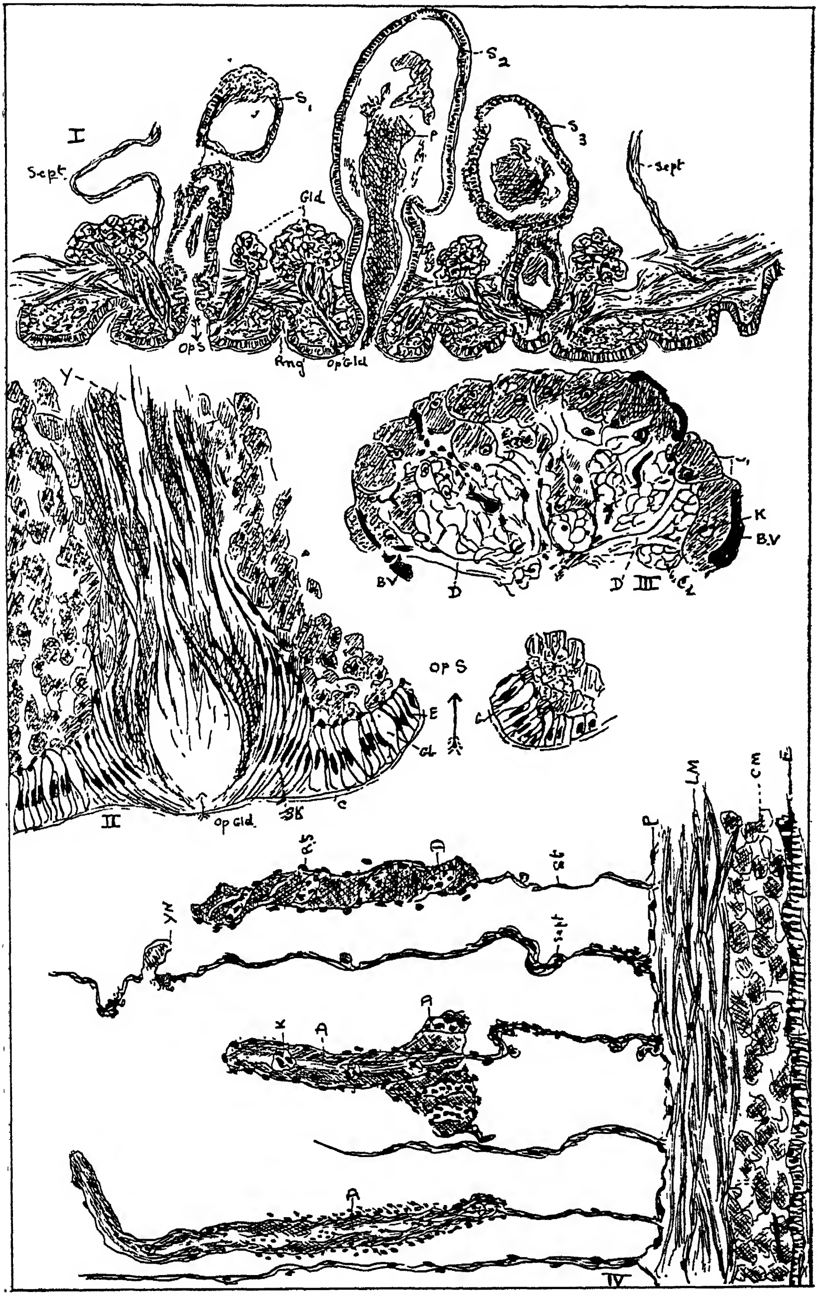
Fig. 4.—Longitudinal section in the region of the possible nephridial organs.



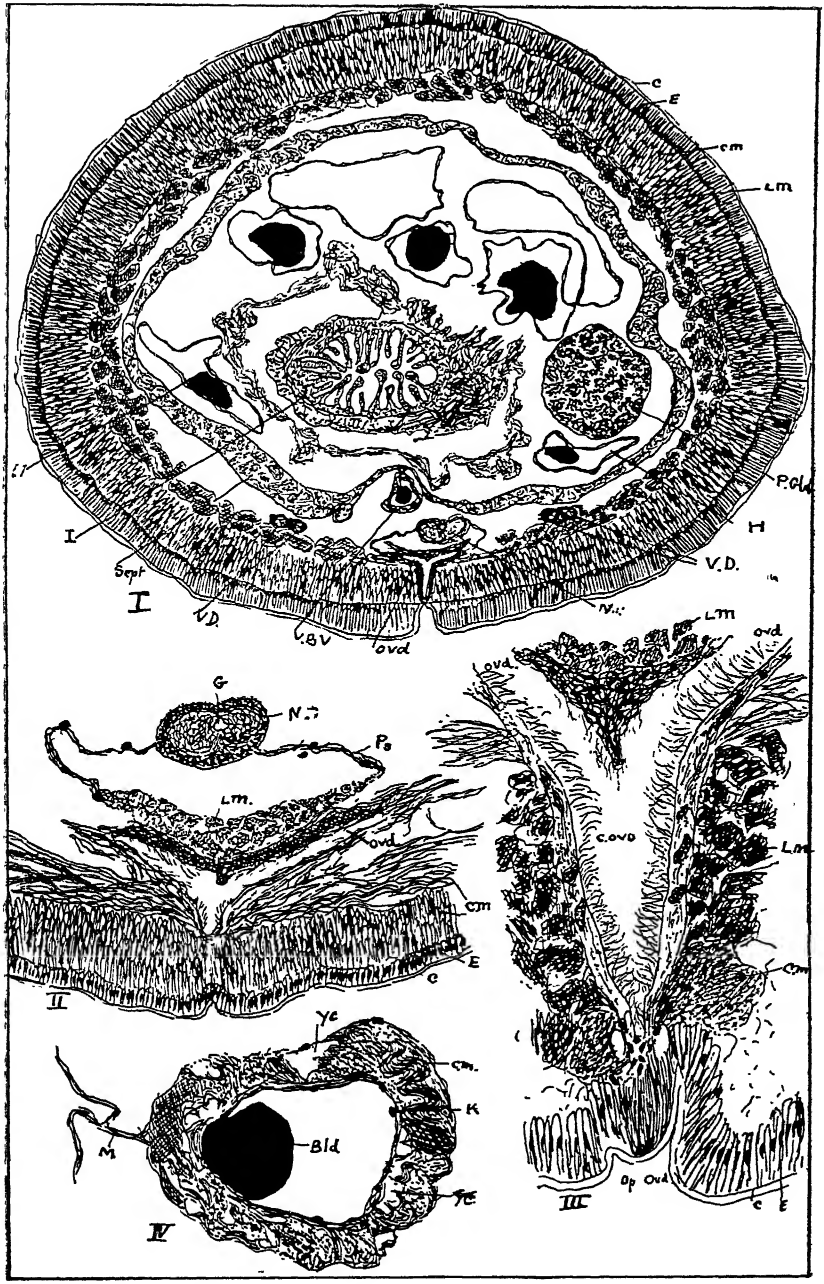
Megascolex Fletcheri, n. sp.



Megascolex Fletcheri



Megascolex Fletcheri



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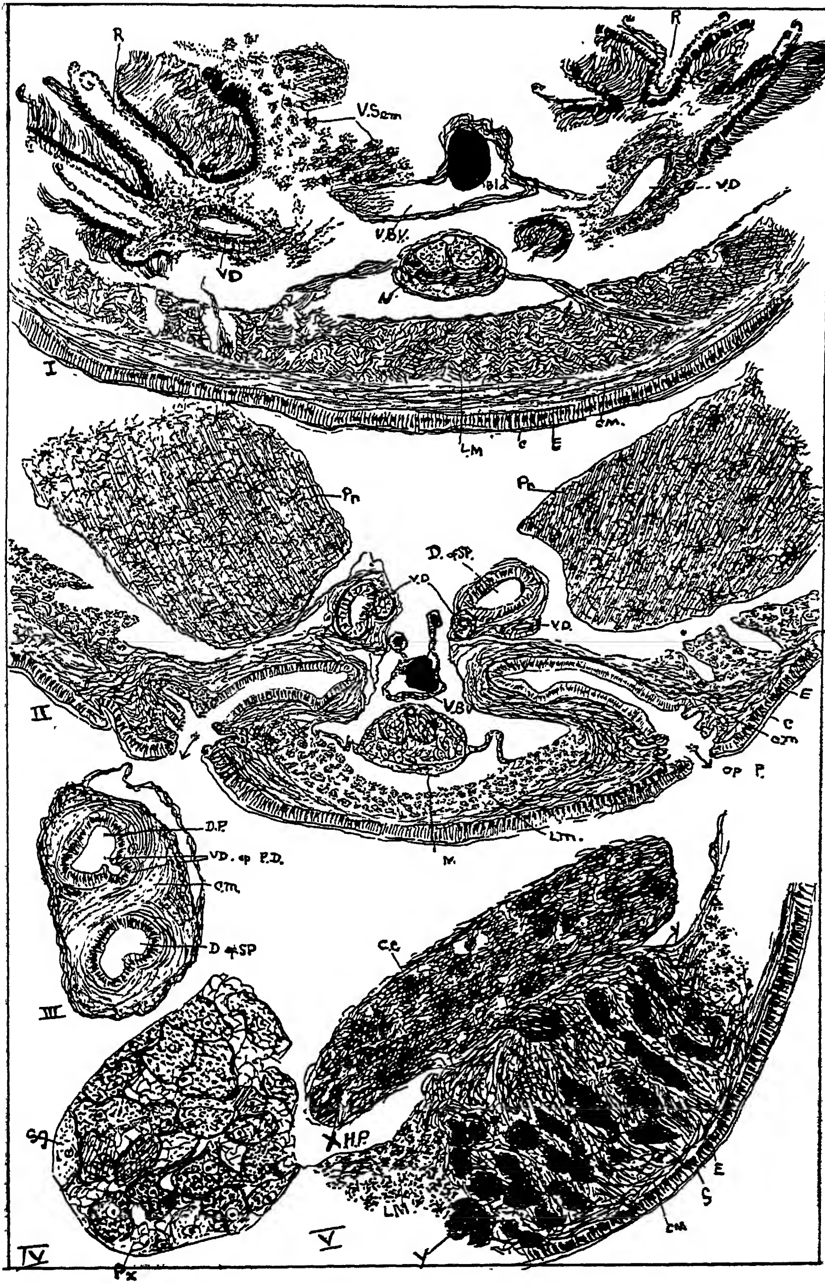

Megascolex Fletcheri

PLATE XXX.

Fig. 1.—Transverse section of earthworm in region of common opening of oviducts.

Fig. 2.—Portion of body wall, with common oviduct passing through it.

Fig. 3.—Drawing under high-powered objective of common oviduct.

Fig. 4.—Transverse section of ventral blood vessel.

PLATE XXXI.

Fig. 1.—Transverse section in region of opening to vasa deferentia.

Fig. 2.—Transverse section in segment eighteen, to show opening of ducts from spermiducal glands to exterior.

Fig. 3.—Transverse section of duct from spermiducal gland, showing opening of vas deferens into it.

Fig. 4.—Part of gland associated with spermiducal gland, under high-powered objective.

Fig. 5.—Transverse section of body wall to show gland associated with spermiducal gland in section.

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ART. XX.—*Notes on Dust Whirls in Sub-Arid Western Australia.*

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[Read December 11th, 1919.]

Introduction.

Dust whirls are well known phenomena in arid and sub-arid countries. They are ascending spiral air currents, which also move in a linear direction, and which carry varying amounts of dust and fine sand with them.

Dust whirls have been well described by W. M. Davis[1] and by E. E. Free.[2] Davis points out[3] that an inflow of air is begun towards the place of ascent, but as the various inflowing currents move for too short a distance to be systematically influenced by the earth's rotation, and as their irregular flow does not allow them to meet precisely at a centre, they turn a little to one side or the other, according as the stronger inflow decides, and a little whirl is then developed rotating indifferently one way or the other. Free also states[4] that the rotation seems to be indiscriminately clockwise, or contra-clockwise, as frequently one as the other.

Dust whirls are recognised to be due to overheating of particular portions of the land surface, with the result that equilibrium is disturbed, and the air rushes upwards. The surrounding air then flows inwards, and a whirl is caused.[5]

Dust whirls have been recorded from various countries, and a valuable list of the literature has been given by Free in the work already cited.

Dust whirls may reach a considerable height. Thus Davis[6] states they may reach a height of several hundred, or even a thou-

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1. "Elementary Meteorology," 1894 p. 201.
2. U.S. Department of Agriculture, Bureau of Soils, Bulletin No. 68, 1911, p. 38, *et. seq.*
3. Loc. cit.
4. Loc. cit.
5. See Free, loc. cit.
6. Loc. cit.

sand, feet; and Free[7] mentions that they are from a few feet to hundreds of feet in height. I. C. Russell remarks[8] that these columns of dust are often 2000 or 3000 feet, or even more, high. At various heights, according to atmospheric conditions, the dust tends to spread out horizontally, and so becomes invisible.

Dust columns are slender. Free remarks that they are a few inches to several feet in diameter.[9] Various observers have pointed out that when seen at a distance, they resemble water-spouts, and that they mostly occur in calm summer weather.

Previous Australian Literature.

Of Australian occurrences, the writer has found few records.

D. W. Carnegie[10] briefly refers to the occurrence of "willy-willies" in arid Western Australia, and states they are sometimes of great violence. J. W. Gregory, with regard to Central Australia, refers to the "dark whirling pillars of sand which slowly travelled up the valley"; also to "three tall columns of dust which were travelling straight towards us"; and again, to "the dust travelling chiefly in two whirlwinds."[11] D. Mawson has described[12] the "willy-willy" of the Broken Hill district, pointing out that they are of the nature of small cyclones, like water-spouts in outline. and that they are columns usually about 20 feet in diameter, rising to a height of several thousand feet. A. Montgomery has remarked[13] in connection with the Western Australian goldfields country, that "on any fine day in summer it is quite usual to be able to see several whirlwind clouds of dust dancing over the landscape at one time."

These are the only Australian records that the writer is aware of.

In sub-arid Western Australia dust whirls are locally known as "willy-willies." They are a matter of common knowledge, but no precise description has, so far as the writer is aware, ever been given of them, and still less is there any record of their mode of rotation, their height and other characters. Even in Australia

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7. Loc. cit.
8. Monograph XI., U.S. Geol. Surv., Washington, 1885, pp. 9 and 154.
9. See also Mawson's estimate mentioned below.

10. "Spinifex and Sand," London, 1898, pp. 254 and 274.
11. "The Dead Heart of Australia," London, 1906, pp. 26, 120, 121.
12. "Geological Investigations in the Broken Hill Area," Mem. Roy. Soc. South Aust., Vol. II., Part 4, 1912, p. 227.
13. "The Significance of Some Physiographical Characteristics of Western Australia." Journ. Roy Soc. W. Aust., Vol. II., 1915-16, p. 83.

as a whole, the records, as noticed above, are scanty. Under these circumstances, some details, which were noted by the writer whilst engaged in geological work in the Niagara-Kookynie district, and, later, in the Comet Vale-Goongarrie districts[14] may be worthy of record. The following notes are, therefore, based on such observations, and relate only to the districts mentioned:—

General Description.

In the districts just mentioned, the climate is sub-arid, and the average rainfall is abouth 10 inches, or slightly less, per annum. Except on the surfaces of the "dry" lakes, there is generally some vegetation; but there is much bare ground between the individual plants.

The dust whirls vary much in height, and perhaps in diameter. Many are but a few feet in height and in diameter, whilst others are hundreds, and probably thousands, of feet high, and perhaps of considerable diameter. The writer, however, has no criteria as to the diameter of the high whirls; but in all instances, the diameter is small compared with the height. The dust whirls are essentially moving columns or pillars. The whirls (as the table below shows) rotate clockwise (that is, in the direction north, thence east, thence south, and thence west), and anti- or counter-clockwise. The anti-clockwise direction predominates on the records obtained. A change from one mode of rotation to the other in the same dust whirl has been noticed, and such change has taken place more than once in the same whirl.

High dust whirls may be practically vertical, or curved, or bent at a high angle to the ground. The curving, or bending, doubtless indicates varying wind velocity at different altitudes.

The dust whirls travel in different linear directions across the country. This linear movement is usually rapid in whirls that are close to the observer. It is difficult to form an opinion about the velocity of distant whirls; and no estimate has been made by the writer as to the actual velocity of near-by whirls. A low whirl, as a rule, dies out within a minute or two, but a high whirl may be visible many minutes, or possibly some hours.

A dust whirl, even a very small one, is quite violent in its action. Dust, sand, grit, and old tins and other rubbish are lifted from, or driven along the ground with great force. When taken

14. The Niagara-Kookynie area is about 115 miles, and the Comet Vale-Goongarrie area about 60 miles north of Kalgoorlie.

unawares by a small dust whirl, one at first receives the impression of the sudden and violent rising of a great wind.

Red is the predominating colour of dust whirls, owing to red being the predominating colour of the soils.

The whirls are commonest in summer, on calm days, or on days with only a gentle breeze. These facts agree with the observations of investigators in other countries. After midday is the most favourable period for the occurrence of dust whirls.

Table of Observed Dust Whirls.

The following list comprises the dust whirls recorded by the writer in the Niagara-Kookynie and Comet Vale-Goongarrie districts, with the dates of occurrence, the direction of rotation, and general remarks. Where it was impossible—mainly on account of distance—to determine the direction of rotation, a blank has been left. In some cases, the direction given is not quite certain, hence a query has been added so as to express this doubt. One gigantic whirl has been separately described below on account of its special interest. The writer is well aware that the remarks as to height and other characters of individual whirls are vague, but the phenomena do not readily lend themselves to accurate measurements, and opportunity did not always permit of more definite statements :—

Date.	Direction of Rotation.	General Remarks.
1914.		
Dec. 18.	Anticlockwise	These occurred in the Niagara-Kookynie district.
,, 18	Clockwise	
,, 21	Anticlockwise	
1915.		
Jan. 8	Anticlockwise	No details, except direction of rotation were noted,
Feb. 10	Clockwise	
,, 13	Anticlockwise	
,, 23	Anticlockwise	
Mar. 29	Anticlockwise	
,, 15		Distant. In front of a ridge. From probable height of latter, the dust whirl was estimated to be 1000 feet high at the least. East of Kookynie.
1916.		
Sept. 22		Distant.
,, 22		Distant.
,, 25	Anticlockwise (?)	Low.[15] On ironstone country.

15. "Low" means that the dust whirl as seen by the naked eye reached to only a small height from the surface of the ground, in some instances, not more than 20 feet, and even less.

Date.	Direction of Rotation.	General Remarks.
Nov. 11 - -	Anticlockwise	Low.
Dec. 5 - -	Anticlockwise (?)	Distant. Fairly high.
,, 6 - -	Anticlockwise	Fairly high.
,, 9 - -	Anticlockwise	Low.
1917.		
Jan. 26		Distant. Hundreds of feet high. Thin, sandy-coloured column. Rapidly changed its form and density. Quickly became invisible. Noted at 3 p.m. on very calm day.
Feb. 6		Hundreds of feet high. Soon became invisible. Day calm and hot. Noted at 1 p.m.
,, 6 - -	Anticlockwise (?)	Hundreds of feet high. Bent in the centre. Visible for a few minutes. Gradually faded away. Noted at 2.30 p.m.
,, 8 - -	Anticlockwise (?)	Distant. Very high. Very distinct, so must have been carrying much dust.
,, 8		Ditto.
,, 8 - -	Anticlockwise	Low. Raised considerable quantity of dust. Soon died out.
,, 12 - -	Anticlockwise	Low. Soon died out.
,, 15 - -	Clockwise	Low. Passed through camp. Lifted fine sand very strongly. Soon died out. About six feet in diameter.
,, 16 - -	Anticlockwise }	Each raised much dust, but soon died out.
,, 16 - -	Anticlockwise }	Diameter of each probably only a few feet.
,, 17 - -	Clockwise	Low. A few feet in diameter.
,, 17 - -	Anticlockwise	Low. A few feet in diameter. Soon died out.
,, 17		Some distance away. Probably at least 100 to 200 feet high.
,, 19 - -	Clockwise	Low. Only about two feet in diameter.
,, 19 - -	Clockwise	Low. Only about four feet in diameter.
,, 19 - -	Clockwise and Anticlockwise	Somewhat higher than last two. Rotated both clockwise and anticlockwise, the change taking place more than once in a distance travelled of 50 or 60 yards. Diameter about 15 feet.

Date.	Direction of Rotation.	General Remarks.
Feb. 19		A gigantic dust whirl. Described separately below. Note.—The 19th February was a typical day for dust whirls, being hot and sultry, with a gentle N. to N.W. breeze. Those recorded were all in the afternoon.
Feb. 20		Low.
,, 26		A gigantic distant whirl. Must have been hundreds, or perhaps thousands, of feet high. Very dark-coloured and dense-looking. Visible for about five minutes, and appeared to be moving slowly southwards. The summit of the column of dust was clearly seen to be spreading out horizontally, as such columns do.
,, 27 - -	Anticlockwise	Low.
Mar. 1		Some miles distant. High, with apparently a fairlv large diameter. Travelling southwards.
,, 1		A very high thin column.
,, 29 - -	Clockwise and Anticlockwise (?)	Low. On samphire flat.
,, 29		Low. On samphire flat.
,, 29		Low.
,, 29		Low.
May 8 - -	Clockwise and Anticlockwise (?)	Rather low. Raised much dust. Travelling northwards. Travelled for a ditance of about half a mile while visible. Direction of rotation almost certainly changed from clockwise to anticlockwise, and vice versa.

Note.—The dust whirls recorded from 22nd September, 1916, onwards, occurred in the Comet Vale-Goongarrie district.

Summarising the above table records a total of 43 dust whirls. Of these 15 have no record as to direction of rotation, 15 are anti-clockwise, four are anti-clockwise with a query, six are clockwise, one is and two probably are both clockwise and anti-clockwise. The anti-clockwise rotation, therefore, predominates. This result could hardly be expected, for if, as appears to be the case, the whirls are of the nature of small cyclones, then in the southern hemispheres, the predominant rotation would be expected to follow

that of the normal cyclones, that is, clockwise. Further observations, however, are required, as the records in this paper are too few to come to a definite conclusion on the point raised.

A Gigantic Dust Whirl.

The whirl now to be described has been noted in the above list, but its occurrence was so striking that a separate description is warranted.

This dust whirl was observed on 19th February, 1917, at about 1.30 p.m., in the Comet Vale-Goongarrie district, when the sun had not passed a great distance beyond the zenith. The day was hot and sultry, with a gentle north to north-west wind. The conditions were, therefore, favourable for dust whirls. This particular whirl formed a great column of dust, the top of which was above two clouds, which were at different levels in the atmosphere, the difference of level apparently being considerable. These clouds were of the cumulus type, and were such as may be commonly observed in the area after midday under the conditions mentioned. The dust column was broken by these two clouds. The column was travelling southward, or south-westwards, at a fairly rapid rate, but the rate of motion could not be determined, and in doing so, passed beyond the clouds, and showed itself as one unbroken, gigantic column, with a pronounced bend forward (i.e., in the direction of its linear movement) at the top. Otherwise it appeared to be approximately vertical. The dust whirl was close to the path of the sun's rays, and as the sun was obscured by the upper cloud, the phenonema could be closely watched. The dust was dull, red in colour, and between the two clouds dense masses of dust could be seen by the naked eye whirling about and springing upwards. As it moved in the direction mentioned, the column became invisible within a few minutes. The direction of rotation could not be ascertained, nor could any idea be formed of its diameter, although the diameter appeared to be about the same through the whole length of the column.

The angle of elevation of the top of the column was guessed to be about 80°, but the horizontal distance of the column from the point of observation could not be ascertained, so that it is impossible to state its height, even very approximately. Judging by observation, it would certainly not be less than one mile distant, and probably much more; but if it be assumed that the distance was

one mile, that the column was approximately vertical, and that the angle of elevation was 80°, the dust whirl would be not far short of six miles in height; and if it were only half a mile away (which, however, seemed altogether too short a distance), the height would approximate towards three miles.

These figures are probably far too high, due, perhaps, to the assumption that the dust column was approximately vertical. The column might appear to be vertical, and yet could perhaps be much bent towards the observer. This would materially reduce the figures.

Another means of checking the height is to ascertain the height of either of the two clouds associated with the dust columns, but no data have been obtained for this. These clouds were two of many similar scattered over, all apparently of moderate height. Again, if the general average height that these clouds form at were known, an idea of the height of the dust whirl would be obtained, but there appears to be hardly any information available as to such clouds in Australia in this connection. Records of other countries show that the upper surfaces of cumulus clouds may be over 3000 feet high.[16] There can be no doubt, however, that this particular dust whirl was of great height, reaching probably to several thousands of feet above the earth's surface, and the quantity of dust raised must have been enormous. When first viewed close to the sun's rays, the dust whirls presented a majestic spectacle.

The writer is indebted to Dr. Griffith Taylor for a reference to Mr. Quayle's Memoir on Clouds, and for some information concerning clouds, which he kindly obtained from Mr. Quayle.

Dust Whirls in Relation to Erosion.

Dust whirls must play an important part in the erosion of sub-arid Western Australia. From the preceding table it will be recognised that they are fairly numerous, even in a small area, and that they include columns of dust of great height. It must also be remembered that, unless high, numerous whirls, even comparatively close to an observer, are not seen by him. If the whole of the sub-arid portions of the State be considered, a vast amount of fine sand and dust must be displaced even in the course of one favourable day. The material is either lifted well into the air, or is dragged along or kept close to the surface of the ground. In the former case the material is chiefly fine dust, and in the latter

16. Davis. Op. cit., pp. 179 and 180.

case, which has been described as a saltatory action, fine sand. The fine dust tends to rise high into the air, and it may be sometime before it settles down to the ground again. During this period it may travel far, and there can be no doubt that a considerable portion of it is carried beyond, or "exported" from the sub-arid areas.

In this way the general surface of these areas as a whole tends to be lowered.[17] The dust which falls in other portions of these sub-arid areas, tends to increase the thickness of soils locally, and also to make these soils of a more heterogeneous character.[18] Such soils are of course subject to removal by dust whirl and other aeolian action, as well as by rain action, but certain areas may receive more wind-blown material than they lose by the same agency.

The fine sand removed by saltatory action immediately settles again when the dust whirl dies out, but during its journey it would tend to collect and to remain in hollows. There is thus probably a general drift from the higher to the lower country (with some exceptions), which aids in keeping the general surface level, and thus in the formation of a vast high level plain—the "new plateau" of the writer.[19]

An interesting account of a dust-storm in south-western North America, and an estimate of the amount of dust precipitated have been recently given.[20] It has been concluded that owing to strong convectional air currents, "an enormous quantity of dust must have been eroded from these arid regions—(New Mexico and Arizona)—lifted into the upper atmosphere, and carried with the storm a thousand miles or more to the north-east, where it was brought down by the snow and sleet, which had formed at a great altitude in the air." It was calculated that not less than a million tons of organic and inorganic material fell, and probably many times that amount. The dust whirls discussed in this paper cannot of course be compared, from an erosional point of view, with such a storm, but nevertheless, the difference is but one of degree.

17. This idea of "exportation" has of course been brought forward by earlier writers, such as von Richthofen and Davis.

18. The mixed character of soils owing to the action of the wind generally has been fully described by Free. Op. cit. p. 109.

19. Bull. 61, Geol. Surv. W. Austral.. Perth, 1914, p. 525.

20. See "Geographical Review," December, 1918, pp. 514 and 515.

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Art. XXI.—*The Physiography and Geology of the Bulla-Sydenham Area.*

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[Read 11th December, 1920].

(With Plates XXXII.-XXXIV.)

Contents.

Cartography.

The area examined covers 20 square miles, and takes in the eastern half of quarter-sheet 7 S.E., and the western portion of quarter-sheet 2 S.W. There are neither dates nor compass points on these sheets.

The date of one edition of the quarter-sheet was probably 1863, but the dates of the other two editions could not be obtained. Two different copies can be seen at the Melbourne Public Library, and a third at the Geological Survey Department. One of the three editions has the Silurian conglomerate south-west of Hanging Valley (Plate XXXII.) wrongly coloured as Kainozoic.

The dips and strikes of the palaeozoic rocks on the quarter-sheet are inaccurate.

In the three editions of quarter-sheet 7 S.E., a large heart-shaped area of tree covered granite, south of Bulla, is wrongly coloured as basaltic.

In the military contour map of Sunbury two errors in road marking occur. In the extreme N.E. of the area the formed road L M (Plate XXXII.) is omitted, while the road N O in the centre west is shown as continuous across the gorge, which is called in this paper, "Column Gully."

The granodiorite boundaries in the N.E. cannot be accurately placed, owing to the gravitation of granitic detritus from the hills. It covers the lower lying basalt, and hides the junction.

Owing to the great accumulation of hill wash along the streams many outcrops are completely covered. This is probably the reason why two conglomerates marked on quarter sheet 7 S.E. are not now visible.

Attention is drawn to the names of the streams in this area, and a study of the geological quarter-sheets, the military contour maps, and the parish plans shows how loose the nomenclature has been. The names of the streams in the parish plans of 1901 differ from those of 1916, and as the names of the latter agree with those given by the local residents, the writer has accepted them for this paper. The eastern branch is Deep Creek, the western branch Jackson's Creek, and the Maribyrnong River (formerly Salt-water River), the stream from the junction of the creeks to the Yarra. The following is a table of the names given to the streams in this area in old and recent publications :—

Publication.	Western Branch.	Eastern Branch.	Combined Creeks.
Geological quarter sheet, 1863	Macedon or Salt-water River	Deep Creek	Saltwater River
Parish Plans, 1901	Saltwater River	Deep Creek	Saltwater River
„ „ 1616	Jackson's Creek	Deep Creek	Maribyrnong River
Military Contour map, 1917	Jackson's Creek	Maribyrnong River	Maribyrnong River
Donald Macdonald in *Argus*, 22/4/19	Jackson's Creek	Deep Creek	Deep Creek above tidal water. Maribyrnong River below tidal water.
Residents and nomenclature followed by writer 1919	Jackson's Creek	Deep Creek	Maribyrnong River.

Physiography.

General Survey.—The dominating feature of the area is the great basalt sheet which slopes gently from the north-west to the south-east, with a slope of 60 ft. per mile, descending from 600 ft. to 300 ft. in five miles. The Deep Creek, Jackson's Creek, and the Maribyrnong River have entrenched themselves in this low plateau to a depth of 300 ft., and they are vigorous young streams, cutting deeper and deeper into a plain that is also very youthful in character. Two granodiorite masses rise 100 feet above the lava surface.

Meanders.—Deep Creek, Jackson's Creek, and the Maribyrnong River meander in a trench about 300 ft. in depth. These streams originally flowed on the surface of the basalt plain, and the slight curves in their old courses became more and more pronounced as the streams deepened their beds. While lateral erosion was at work deepening the curves, vertical corrosion was deepening the valley, and this combined action has resulted in an alternating series of spurs and river cliffs along each stream. Waterworn pebbles of basalt, quartz, quartzite, etc., along each spur, afford evidence of the former position of the stream. This type of meander is in sharp contrast to the flood-plain meander, where only lateral erosion is active.

Several writers (1) describe an entrenched meander as one where the original meander has been preserved, and where the opposite banks of the stream make approximately equal angles with the surface of the ground. According to these geographers, the spurred meanders of Bulla and Sydenham would not be entrenched meanders. W. M. Davis, however, refers to the spurred character of the entrenched meanders of the Meuse and Seine. (2b) It is important to note that the present meanders of Deep Creek are not simply the preserved meanders of the old stream, as indicated by J. W. Gregory (3). The length of the present curves is very much greater than that of the old curves, owing to the lateral swinging of the streams, but the radii of the curves have remained approximately the same, (2a).

Down-valley Sweep of Meanders.—This sweeping movement is not so pronounced as in streams flowing through soft rock, but the effect can be definitely seen in most of the spurs along either creek and in the position of the small flood plains. The spurs are not symmetrical in section, the steeper side always pointing up-

valley. This also has the effect of sharpening the spur, and the placing of the flood plain, not at the end of the spur, but on the down-valley side of it. (2a.)

Meander Belt.—In youthful streams, such as Deep Creek, the belt of wandering and the meander belt coincide with one another. The stream by lateral swinging widens its meander belt, but this tendency is checked by (a) the down-valley sweep of the meanders (which would eventually cut through the spurs), and by (b) the formation of new channels at flood time across low spurs.

Relation between Radius of Meander and Volume of Water.—W. M. Davis has shown (2a and 9), that the radius of a meander, where slope and load are equal, is proportional to the volume of water. This is exemplified in Jackson's Creek, Deep Creek and the Maribyrnong River. Jackson's Creek has a slightly smaller volume than Deep Creek, and the radii of its meanders are slightly smaller than those of Deep Creek. Similarly the radii of the Maribyrnong meanders are considerably larger than those of the creeks.

Hanging Valleys.—Excellent examples of hanging valleys are found along both Jackson's Creek and Deep Creek. In every case these tributary streams flow only after heavy rain. The best example is that to the south-west of the main granodiorite outcrop. This small stream has been formed along the junction of the basalt, and the granodiorite. At its junction with Deep Creek there is a fall 80 ft. in height. Owing to their poor supply of water the tributary streams are unable to corrode their beds as rapidly as the main streams. This is the chief cause of the lack of adjustment between the tributaries and the main streams in this area. At Hanging Valley (see Z, Plate XXXII.), this lack of adjustment is increased by the hard compact hornfels in its lower course.

Deserted Bed of Jackson's Creek.—An old accumulation of boulders can be seen in the right bank of the Maribyrnong River, a quarter of a mile south of the junction of the creeks. Some of the boulders are huge, some small, some of basalt, some of conglomerate, and others of sandstone, but none of granodiorite. It was the old bed of Jackson's Creek which deserted it when it flowed 6 ft. above its present level. If Deep Creek had contributed boulders to the conglomerate, granodiorite also would have been represented.

Corrosion.—A study of the effect of the volcanoes on that section of Jackson's Creek north of Sunbury would provide interesting matter, for it is evident that the Sunbury volcanoes in late Kainozoic times, formed an immense bar across the old Jackson's Creek, and overwhelmed the valleys to the south beneath a flood of lava.

It will be noticed that Deep Creek flows close to the boundary of the granodiorite, and the basalt. Originally it flowed along the junction. As Deep Creek deepened its bed, the granodiorite became exposed on both banks. It is probable that streams such as the Yarra and Deep Creek tend to flow at the junction of basalt and older rock because hill drainage helps to form a valley at the junction of the bedrock, and the lava sheet, and because the lava flow is probably depressed at the edges, and thus directs the drainage of the area to the line of junction.

By meandering and deepening the streams have reduced the slope from ·60 ft. per mile to 18 ft. per mile. From the creek junction to the most northerly point of Deep Creek, marked on the map, is 7 miles. In this distance it falls from 280 ft. to 150 ft., giving a slope of 18 ft. per mile. It is remarkable that Jackson's Creek from the north-west boundary on the map to the creek junction flows 11 miles, and falls from 350 ft. to 150 ft., giving again a slope of 18 ft. per mile. The slopes are interesting when compared with that of the sluggish Mississippi, which has a fall of less than 1 ft. per mile. At the Bulla School the creeks are only half a mile apart, but, owing to the short distance along Deep Creek to the junction as compared with that along Jackson's Creek, the bed of Deep Creek is 60 ft. lower than that of Jackson's Creek. This illustrates the fact that in river capture the more vigorous stream may be captured by the less vigorous. Jackson's Creek and Deep Creek having the same slope, are of equal vigour, but if their valleys met Deep Creek would capture the head waters of Jackson's Creek.

Deep Creek has been superimposed along the whole of its course on the older rocks beneath. Jackson's Creek is still cutting into basalt, though it frequently carves its way across the tops of the old Ordovician and Silurian hills.

Basalt bars of greater density retard its rate of deepening by checking its velocity. In several parts Jackson's Creek resembles a series of small lakes separated from one another by basalt bars over which the water tumbles in miniature rapids.

Headward Erosion.—The extremely youthful tributary streams frequently become gorge-like, and tend to cut back across the fields. Farmers in this locality meet the problem by piling boulders at the head of the tributary and planting hardy shrubs around them in order to check the velocity of the water, and thus retard the transport of material. The early neglect to check the headward erosion of youthful streams has led elsewhere to great loss of land. A large area at Coburg has been rendered unfit for habitation within the last thirty years, and the same will occur at Aberfeldie, near the Essendon sand pits, if preventive measures are not taken soon.

Near the school at Bulla an extremely young active tributary has cut back from Deep Creek and formed a canyon in decomposed granodiorite and basalt. Apparently no effort has been made to check the headward erosion, and now it is completely out of hand, and threatens the roads north of Bulla. The canyon is about 60 ft. in depth. It is not likely to deepen further for many years, as its floor is nearly adjusted to the present level of Deep Creek. Lateral erosion is now rapidly increasing the area of destruction.

Basalt Outliers.—A small outlier is seen in the south of the large granodiorite outcrop, and another in the extreme centre-north in Ordovician sediments. They represent small basalt tongues that have been cut off from the main lava sheet by river action.

Palaeozoic Rocks.

General Description.—The bedrock of the area so far as is known consists of Upper Ordovician and Lower Silurian sediments in the form of shales, sandstones, conglomerates, quartzites, slates and hornfels. These have been strongly folded by approximately east and west pressure, and the prevalence of easterly dips suggests overfolding to the west. The folds pitch to the north, and this pitch makes the strike of the strata somewhat irregular.

Throughout the district these palaeozoic rocks have been highly fractured and faulted, most of the faults being reverse strike faults. On the left bank of Deep Creek, at the mouth of Hanging Valley, is a fault breccia altered to hornfels by the granodiorite intrusion.

If the conglomerate (C_3), near Hanging Valley, and conglomerate C_1 or C_2 on Jackson's Creek, be parts of the same stratum,

lateral displacement must have taken place, and, though this is the probable explanation, yet local lenticular accumulations of conglomerate may be the reason why these bands do not appear on the same line of strike. Owing to intense pressure, well defined joint planes have been set up which tend to break the strata into small rhombohedra. These joint planes give difficulty in the taking of dips and strikes, as they closely simulate the bedding planes.

Palaeozoic Fossils.—Previous to 1918, Upper Ordovician graptolites had been found in the extreme north-west of this area (4), while Lower Silurian graptolites had been found in the extreme south-east (5), but none had been found between these localities.

In 1917 and 1918 the writer came across several fossil beds whose position is indicated on Plate XXXII. The paucity of fossils in this locality is probably due partly to dynamic and thermal metamorphism, which prevent the rock splitting along the bedding plane, and partly to the sandy nature of the sediments.

It has been suggested that the conglomerate C_1 is of glacial origin, and the absence of fossils in this neighbourhood is due to the severe climatic conditions that prevailed during their deposition. (6.) Fossils have, however, now been found in the following localities:—

(a) On the left bank of Jackson's Creek, 50 yards north of the mouth of Column Gully. (See Plate XXXII.) In a very narrow band Upper Ordovician graptolites can be obtained in abundance, Coenograptus and Diplograptus being the commonest genera. The fossils are well preserved, but are rapidly obliterated on exposure to the air.

(b) On the left bank of Jackson's Creek, half a mile south-east of the Organ Pipes. For nearly a mile along both banks of the creek, the rocks contain enormous numbers of worm impressions. On the rock face a few yards south-east of dyke D_6, the markings strongly suggest worm burrows, but Mr. F. Chapman says that they are probably the remains of the soft part of the worms. The impressions are quite different from those of Trachyderma (7). From the graptolite bed referred to in (a) to the conglomerate C_1, these impressions occur in varying numbers. The upper part of each stratum has more impressions than the lower part, and many of the most prominent markings are perpendicular to the bedding plane, and increase in diameter from below upwards.

Mr. F. Chapman has not been able to determine the age of these worms, but as there is field evidence that they are of Ordovician age, they will be called tentatively in this paper the "Ordovician worm beds."

(c) On the right bank of Jackson's Creek, at the mouth of a small gully, 30 yards east of conglomerate C_1. Here impressions of the gill plumes of the worm Trachyderma sp. occur, in two very narrow bands.

(d) The best impressions of Trachyderma were found on the right bank, about 300 yards down stream from the conglomerate C_1. At this spot Trachyderma and Monograptus were obtained on the same slab. Many of the strata here yield the tubes and gill plumes of this worm, which Mr. F. Chapman has connected with the gill plumes found at South Yarra in Lower Silurian rocks. (7).

(e) On the right bank of Jackson's Creek, 30 yards north-east of the dyke D_3 (Plate XXXII). The writer found three or four species of Silurian graptolites. Graptolites from localities (d) and (e) were sent to Mr. F. Chapman. They have not been named yet, but were pronounced to be definitely Silurian.

(f) At the point x (Plate XXXII.), fossils were found about 1862 (4), by members of the Geological Survey. Mr. F. Chapman has stated that these fossils are definitely Silurian.

Junction of the Upper Ordovician and Lower Silurian.—Previous to 1918 the junction between the Silurian and the Ordovician rocks had been placed one mile S.S.E. of the junction of the creeks (6). As neither unconformity nor fossils had been found, geologists were forced to rely on the study of dips and strikes, and on this evidence alone the placing of the junction there seems to have been justified, for there the dips become lower and the direction of the strike is slightly altered. In this area it is not safe to put too much reliance on variation in strike and dip, because these are much disturbed by faulting, pitching and hill creep.

Two of the three editions of the geological quarter sheet No. 7 S.E., show the Ordovician rocks extending to the S.E. margin, while quarter-sheet No. 2 S.W. shows Silurian extending to the S.W. margin, thus making the edges of the sheets coincide with the junction between the Ordovician and Silurian sediments. A third

edition of the quarter sheet 7 S.E., places the junction one-eighth of a mile to the west of this, and this is approximately the line found independently by T. S. Hart (6).

The presence of Silurian graptolites in two localities one and a-half miles west of this junction, and in another one and a-half miles N.N.W., strongly suggests that the junction shown in the quarter sheets is incorrect. There is of course the possibility that the later Silurian rocks occupy an infolded pocket of the Ordovician. In either case we are forced to look for the junction further upstream. It seems to the writer probable that the western face of conglomerate C_1 is the junction. The reasons for putting it there are as follow:—

(a) The junction is necessarily between dyke D_3 and Column Gully, for at the former, Silurian graptolites and worms are found, and at the latter, Ordovician graptolites. These two places are approximately one and a-half miles apart. No conclusive evidence is given by the dips and strikes, for though slight variations occur, up-stream and down-stream similar variations can be noted. In the Ordovician graptolite bed the dip is 84°E, and the strike exactly north and south, while in the Silurian graptolite beds the dip is 77°E, and the strike 8° west of north. Between these two beds there is no sudden change of dip or strike.

(b) The Silurian worm Trachyderma can be found in many of the strata east of C_1, but not west of it.

(c) "Ordovician worm impressions" are found in enormous numbers, from the Ordovician graptolite beds, where they are associated with Diplograptus, right up to the conglomerate C_1, but neither in it nor on the east side. The fact that these marks suddenly cease at the conglomerate strongly suggests discontinuity of conditions.

(d) The conglomerate itself is strictly conformable with the strata on the eastern side, but on the western the contact is very irregular. The one drawback to the placing of the junction at C_1 is the presence of a few pebbles in the strata on the up-stream side of the conglomerate. This suggests similarity of conditions, and though their presence is not fatal, yet it makes one hesitate to accept C_1 as a basal conglomerate.

Palaeozoic Conglomerates.—The four palaeozoic conglomerates in this area have been carefully described by T. S. Hart (5). C_4, the most northerly, is wrongly coloured tertiary in one of the three quarter sheets. It has been pointed out (6) that this conglomerate has been so indurated by thermal metamphorism that the matrix is as hard as the old quartzite pebbles, and thus the pebbles do not weather out.

The southern exposure C_3 can be picked up in a runnel on the cliff about 80 ft. above the stream. It is not altered to the extent that C_4 is.

C_2 shows the clay bands much distorted by differential pressure, as they are in the Italian Cutting, Daylesford (8).

C_1 is the largest of the four conglomerates.

T. S. Hart (6) puts forward various reasons for considering it an Ordovician glacial conglomerate. His conclusions appear incorrect. The following is a summary of the reasons given on which he based his conclusion :—

(1) A part of the conglomerate is a mixture of pebbles and fine clay.
(2) The strata are much disturbed in places.
(3) The matrix is angular.
(4) Some pebbles are facetted and striated.
(5) Fossils are absent on account of severity of the climate at that period.

The writer carefully weighed these points, but was forced to discard the theory of the glacial origin. A mixture of pebbles and clay can be formed in other ways than by glacial action, and the disturbance of the strata appears to be the unconformable junction of the Ordovician and Silurian. The presence of the striations on an insignificant percentage of the pebbles can be accounted for by the fact that when conglomerate bands are folded under pressure, the hard pebbles grind against and scratch one another. Facetted pebbles were not common in this conglomerate, and there was quite as large a percentage in the river conglomerate as in the ancient collection. On examining under the miscroscope, the matrix from conglomerate C_1, and comparing it with material taken from other strata, it did not appear to be more angular than the latter. It has been shown already that life was abundant in the seas in that age.

The direct evidence against this glacial theory is :—

(a) The general linear arrangement of the pebbles.

(b) In C_1 the pebbles lie regularly on their flat faces.
(c) Pebbly, sandy and clay bands alternate.
(d) Most of the stones are small. Not one large stone is seen. If it were glacial you would expect to find some boulders.
(e) Facetted and striated pebbles are extremely rare.
(f) Many strata contain pebbles of only one size.
(g) The conglomerate is almost certainly of Silurian age, and no other evidence of Silurian glaciation has been reported in Australia.

For the reasons above it seems more likely that the conglomerate C_1 is the basal conglomerate of the Silurian rather than an Ordovician glacial deposit.

The material of which the pebbles are composed is similar to that of the Kerri conglomerate found along Conglomerate Creek, near Macedon (10). There are quartz, quartzite, black chert, quartz-porphyry, greisen and diabase pebbles. The Kerri conglomerate contains a large percentage of dimpled and squeezed pebbles, whose state it has been shown is probably due to solution under pressure (10). Many similar pebbles are found in C_1 but most of the dimples have not been made in situ, for frequently the dimples are opposed not to a pebble, but to the clay matrix. A few of the dimples may have been made in situ.

Metamorphic Rocks.

These are exposed along Deep Creek to the north, west, and south of the granodiorite. At and near the junction the sediments have been converted into hornfels, while further away they occur as spotted shales, or as indurated sandstones or shales. The width of the aureole varies considerably, probably owing to the irregular junction of the granodiorite, with the sediments beneath the surface. As far as can be judged from the bedrock exposed along the creeks the hornfels belt on the average appears to be about a quarter of a mile wide, and it gradually merges into spotted slate, which is not uniform in its distribution. The indurated sediments have abundant secondary mica.

In the hand hornfels is a hard, dense, dark rock, in which individual crystals cannot be seen with the naked eye. Under the miscroscope, however, it is seen to have abundant secondary brown biotite. Near the contact there is a considerable amount of cordierite produced, but further away andalusite, biotite, and secondary quartz predominate. The cordierite can be distinguished from

the quartz by its cleavage, which is easily picked out, and by the numerous and characteristic inclusions. A little tourmaline is found in a few sections, but secondary quartz is present in abundance in all.

The hornfels close to the contact is very much coarser than that some distance away.

Owing to the quantity of sandstone which characterises the palaeozoic rocks of this area, a considerable amount of quartzite has been formed, much of it being thermal metamorphic in type.

It is interesting to note the difference between the action of running water and the weather on these metamorphosed sediments. They appear to be highly resistant to the latter, but readily succumb to the former, owing to the presence of three sets of joint planes, which divide the rocks into variously shaped rhombohedra. The result is that the stream in flood can break out the rhombs and thus deepen its bed, whereas the ordinary atmospheric agents are not so successful. The importance of jointing is shown near Hanging Valley, where a metamorphosed fault rock of the same material as the hornfels around it has more sucessfully resisted destruction by Deep Creek. The fault rock is not jointed, and the normal hornfels is, thus enabling the stream to remove it block by block.

Granodiorite.

Six outcrops are mapped, three large and three small, and they roughly form a ring round Bulla. The boundary of the north-east outcrop is hidden by later detritus, that has gravitated down from the east. The five outcrops to the north stood out as islands in the lava flood, but the most southerly was overwhelmed by it.

Chemical Character.—The material for analysis was obtained from fresh rock that had been "plug and feathered" on the main outcrop southwest of Bulla.

It was analysed by Mr. F. Watson, and the analysis is given in the following table, together with analyses of other similar rocks for comparison :—

	Granodiorite Hesket	G'diorite Pory Barringa Ck.	Granodiorite Harcourt	Granodiorite Bulla	Adamellite Ingliston	Adamellite Trawool	Adamellite Mt. Gellibrand
SiO_2	68.92	71.65	70.91	66.13	71.57	69.19	67.75
Al_2O_3	15.26	14.56	13.99	16.83	13.58	13.45	16.11
Fe_2O_3	.80	1.13	.35	1.11	1.18	2.71	.50
FeO	3.30	1.56	3.02	4.17	2.19	2.78	4.00
MgO	1.64	.84	.80	1.83	1.07	1.06	.79
CaO	3.04	1.27	2.35	3.25	1.72	2.04	2.68
Na_2O	2.71	2.76	3.94	2.25	2.79	2.89	2.60
K_2O	2.93	4.14	3.66	3.14	4.36	3.94	3.42
H_2O + 110	1.04	.15	.21	1.68	.69	.77	.96
H_2O − 110	.22	1.20	.11	.23	.11	.16	.20
CO_2	Nil	Nil	Nil	Tr.	.29	.07	Nil
TiO_2	.70	.35	.58	Tr.	.46	.51	.85
P_2O_5	.19	.12	Tr.	Tr.	.11	.18	.09
MnO	Tr.	.04	Nil	.07	.09	.14	Tr
Li_2O	Tr.	Tr.	—	—	Tr.	Tr.	—
Cl	Nil	Tr.	—	Tr.	Tr.	Tr.	—
Total	100.75	99.77	99.95	100.70	100.21	99.89	99.95
S.G.	2.688	2.630	—	2.677	2.655	2.666	2.68
	Mines Dept.	Mines Dept.	G. Ampt.	F. Watson 1918	A. G. Hall	A. G. Hall	H. C. Richards

The rather high CaO content, and the relatively low K_2O content of the Bulla rock favours granodiorite rather than adamellite, and the miscroscopical examination confirms this determination.

Megascopic Character.—It is a rather coarse grained, grey rock with many crystals, 10 mm. in diameter. Quartz, plagioclase, orthoclase, biotite and a little pyrite can be seen. The quartz has a greasy lustre, and the felspar tends to be greenish. The rock takes a fine polish, though the coarse biotite is inclined to give the surface a chipped appearance. Basic segregations with their rounded outlines are very common. The specific gravity of fresh rock is 2.677, and thus in keeping with its determination as granodiorite.

Microscopic Character.—It is a non-porphyritic, hypidiomorphic, holocrystalline rock with crystals of various sizes. It is medium to coarse in grain, with a rich assortment of minerals.

The following are present in order of decreasing abundance:—Andesine, quartz, orthoclase, biotite, chlorite, sericite, muscovite, apatite, pyrite, magnetite, arsenopyrite, calcite and zircon. The chlorite, sericite, pyrite, calcite, and arsenopyrite are secondary.

The extinction angles of the carlsbad and the lamellar twins disclose the fact that the plagioclase is basic andesine. Zoned crystals are very abundant, and the zones are seen to be more basic as the centre is approached. Certain bands of the zoned felspars were sericitized before the others, showing that felspars of that composition were not so stable in the presence of sericitizing agents. Generally sericitization took place from the centre outwards, i.e., from the basic to the acid plagioclases. In the sections studied sericite in its turn tends to be kaolinized.

Summary.—The rock from its chemical and mineral composition and its physical properties is a slightly altered granodiorite. In the hand it appears fresh, and shows no sign of weathering.

In the field it undoubtedly appears to be linked to the Gellibrand mass, which has been described by Dr. F. Stillwell as adamellite (11). Both are 500 ft. high, and have the same mineral composition, and approximately the same chemical composition. It differs from the Gellibrand stock in having a slightly higher lime content, and slightly lower silica content.

Dr. F. Stillwell found that the proportion of plagioclase to orthoclase was less than 2:1 in the Gellibrand stock, but the writer by the Rosival method found the proportion distinctly more than 2:1 in the Bulla stock, which is adjacent to it. Slight differences in mineral and chemical composition are probably local, for the two rocks are similar in all other important characters.

Granitic Intrusions.—Near Hanging Valley is a granitic dyke 20 feet wide, intruding the hornfels. Near the southern edge of the main granitic mass there are several small dykes of microgranite intruding granodiorite, while north of Bulla bridge there is a dyke of aplite and a small one of quartz, both in granodiorite.

The dyke near Hanging Valley is evidently a tongue from the main mass, but the microgranite, aplite and quartz tongues appear to have been derived from the acid residue of the magma after the outside portion had cooled and hardened. The magma evidently stoped the palaeozoic sediments so quietly that the dip and the strike are not only unaltered up to the southern contact, but are continued at the northern junction. The sediments to the west also are undisturbed.

A large number of angular and irregular rock blocks are found embedded in the granodiorite along Deep Creek, S.W. of Bulla. That they were originally blocks of sediment that were displaced by the stoping, and then sank into the molten magma, might be inferred by the angularity of the blocks, and by their close similarity to hornfels. If they were basic segregations, you would expect the outlines to be rounded.

Economics.—The best granodiorite for building purposes lies between the deep trenches of Jackson's Creek and Deep Creek, at the 500 ft. level. The expense of hauling blocks of granodiorite across these deep trenches and thence to Melbourne practically prohibits the use of this rock as a building stone.

The granodiorite, in striking contrast to the basalt of this area, is always tree-covered, and with the exception of the trees in the deep creek trenches, is the only local source of timber.

Kaolinized Granodiorite.

Location.—The granodiorite at several places round Bulla and Broadmeadows has been kaolinized. In the area under discussion there are four extensive masses of kaolinized granodiorite, and several smaller outcrops. Two of the large outcrops are being worked by Cornwells for their Brunswick pottery. The others have not yet been opened up.

Description.—At the quarry Q^1 (Plate XXXII.) one can trace the change from hard granodiorite, through the partly decomposed to the thoroughly decomposed and whitened rock. Decomposed basic segregations can also be seen in the face. Much of the mass is left the purest white by the leaching out of the iron oxide derived from the magnetite, pyrite, biotite and chlorite. In other parts the decomposed rock is deeply stained and cemented by the concentration of iron oxide.

In the smaller quarry (Q_2) near the Bulla school, there is a well-marked vein one inch thick, of bluish tourmaline and granular quartz, in a joint plane of the kaolinized granodiorite. Another vein $1\frac{1}{2}$ inches thick has lately been cut out of the kaolin in Q_1.

The quartz granules of the original granodiorite persist, apparently unaltered, throughout the kaolinized mass.

Microscopic Examination.—Angular quartz is surrounded by crystallised kaolin, which appears chiefly as twinned lamellae, though often in the form of scales and aggregates. A considerable amount of sericite is still present, with earthy calcite and zircons.

Origin of the Bulla Kaolin.—Granodiorite may be kaolinized by the action of meteoric water carrying carbon dioxide in solution, which penetrating the granodiorite decomposes the biotite and felspars. Kaolin in Fiji and the Dublin Mts (Ireland) is stated by Prof. Sollas to have been formed in this way (12).

Probably a commoner process of kaolinization and the proved origin of the vast kaolin masses of England and United States (12 and 13) is that of pneumatolysis, where emanations of carbon dioxide, boron, fluorine, or chlorine, probably with steam, have decomposed the felspars and biotite of the plutonic rock.

Three investigators, E. J. Dunn, 1899 (15), R. W. Armitage, 1911 (14), and F. Stillwell, 1911 (11), have briefly discussed the Bulla kaolin. While both Mr. Armitage and Dr. Stillwell refer to the possibility of either surface water or pneumatolysis being the cause of the kaolinization of the Bulla granodiorite, the former favours the meteoric origin and the latter the pneumatolytic origin.

For the following reasons, it seems probable that pneumatolysis and not meteoric water is responsible for the kaolin of this area.

Evidence Against the Meteoric Theory.

(a) Only Isolated Outcrops Occur in Victoria.—This is strongly against the meteoric theory, for if the water and carbon dioxide were subaerial one would expect kaolin to be found in all parts of Victoria, where the old granitic surface is protected from denudation.

(b) Only Isolated Outcrops Occur at Bulla.—There are about ten outcrops at Bulla, and these are separated from one another by solid, unaltered granodiorite. Generally the surface of the granodiorite is protected by basalt and gritstone, and yet only relatively small outcrops of kaolin are found.

(c) Relation of Kaolin to the Sites of Old Valleys.—It has been stated (14) that the Bulla kaolin always underlies basalt which is situated in the sites of old pre-basaltic valleys, and that the drainage beneath and through the basalt would thus tend to be gathered along lines where it could attack the granodiorite vigorously.

In reply to this it can be stated that kaolin does not always underlie the basalt. In the largest Bulla quarry, Q_1, the kaolin is overlain by a considerable thickness of grits. The presence generally of basalt over kaolin is only what one would expect. Suppose

a granodiorite mass had been converted into kaolin at various places by pneumatolysis long before the lava floods. At these places the weathering would be much more rapid than where the rock was unattacked. Depressions would be made, and, later, occupied by the lava, while the fresh and less denuded rock would stand up as a monadnock above the molten basalt.

(d) Fresh Granodiorite under Basalt.—In two places fresh, hard granodiorite was seen directly beneath basalt at a low level, while the granodiorite to the side of it had been kaolinized. At another place granodiorite was seen under basalt that had flowed into an old valley. There was no sign of kaolinization.

(e) Shape of the Outcrops.—In this area the shape of the outcrops is not very definite, but where it is shown it agrees with type (a), (Fig. 1, Plate XXXIII.) If the kaolin were of meteoric origin, it would be of type (b) (Fig. 2, Plate XXXIII.).

(f) Relation of Kaolin to Depth.—In every case the rock near the bottom of an outcrop is as much altered as that higher up the face. If the decomposition were due to surface water and carbon dioxide, then decomposition should decrease as the depth increased, for the solid rock deep under the surface stream would suffer very little from downward drainage.

(g) No Evidence of Stream Beds above the Kaolin.—If the kaolin were formed by water in old valleys draining through granodiorite, some trace of stream material above the kaolin would very likely be found. No trace of river gravels, silt or conglomerate was found above any of the kaolin masses.

(h) Kaolin Found at Many Levels.—Kaolin can be found right from the level of the stream to 200 ft. above it. One would not expect such differences in level in separated outcrops if old valley floors determined the point of attack on the granodiorite by the stream water with carbon dioxide in solution.

(i) No Evidence of Kaolin Being Formed in Present Stream.—The granodiorite along Deep Creek and on the hill sides is not kaolinized. If kaolinization be due to subaerial agencies, why has not the granodiorite in this stream bed been kaolinized?

(j) Accompanying Minerals.—Kaolinization by pneumatolysis is generally accompanied by the production of tourmaline, fluor, cassiterite or topaz, which cannot be produced by subaerial agents. A vein of tourmaline in Q_1 and another in Q_2 (Plate XXXII.) give valuable positive evidence that magmatic vapours have been present to some extent at least.

Summary.—The microscopic examination of the kaolin gives no definite evidence in favour of either theory, but the field evidence, while producing little positive evidence in support of pneumatolysis, strongly discounts the meteoric theory. The fact that no fluor, cassiterite, or topaz is found in the kaolinized rock, and only a small amount of tourmaline, rather suggests that we must turn to magmatic water and carbon dioxide as the agents causing kaolinization, as in Cornwall and in the United States (12). The earthy calcite in the sections of the kaolin supports this conclusion.

Economics.—Fifty years ago a company was formed to export this material to England, where it was bought at 18/- per ton. Owing to the heavy transport cost the company failed.

At present the kaolin in Q_1 and Q_2 is being worked by Cornwells, who use it for making fire bricks and other articles used at high temperatures. There is a growing export trade in these manufactured articles.

On account of the trace of iron in the Bulla kaolin, it has not, up to the present, been used for chinaware. The quantity of kaolin appears to be unlimited.

Kainozoic Rocks.

Older Basalt.—In the south-east of the area three lenticular outcrops were found. The most northerly is vesicular, and rests directly on Silurian sediments, and underlies a very thick cap of stratified Kainozoic grits. The best section, however, is seen in a cliff face in the extreme south-east, where very decomposed older basalt overlies a pre-older basaltic river conglomerate, about 8 ft. in thickness, which merges into sands at the sides. This sand and the sandstone conglomerate beneath the basalt are strictly local in origin, and remind one very much of the sands underlying and overlying the leaf beds two and a-half miles to the N.N.W.

In this decomposed basalt there are, in situ, several undecomposed basaltic nodules. These remove all doubt as to the identity of the outcrop. The basalt thins out at the edges, and here the underlying sand has in part been altered to quartzite, and the overlying sandy clay to a rock resembling red brick. Newer basalt more than 100 feet in thickness rests on these beds.

Pre-older-basalt River Valley.—The alignment of the three southern outcrops is indicative of an old river valley, and this

conclusion is upheld by the presence of a conglomerate in the southern exposure.

No evidence of stream action in the two patches to the north was found, but this may have been hidden by the talus, which masks the surface. The northern outcrops are at a lower level than the southern one, and this suggests that the stream in this locality flowed to the N.N.E.

Basic Hypabyssal Rocks.

Along Jackson's Creek, in the south of the area, there occur at least seven basic to ultrabasic dykes. D_4 between D_1 and D_2 can be seen only when the creek is very low. In places it is sill-like. D_1 is 22 ft. wide, and is found directly beneath the "Organ Pipes," but separated from them by Kainozoic grits. D_3 contains nodules of relatively fresh material, the only unaltered mineral being apatite, though abundant augite and olivine can be recognised by the shape of the old crystals and their alteration products. Oblong outlines which may have been plagioclase laths are fairly numerous. The apatite has a vitreous to subresinous lustre. Its shape is remarkable, for it resembles a miniature torpedo. Frequently the crystals are long, but flattened. They can be obtained up to $1\frac{1}{4}$ in. in length, and down to the smallest needles. All have smooth rounded outlines, but some have small smooth depressions. The smooth outlines and depressions are evidently due to corrosion by the magma. Owing to the extreme brittleness of these crystals, it is difficult to obtain complete specimens. From carefully chosen fragments the S.G. was found to be 3.104, and the P_2O_5 content 40.3 %. A brisk effervescence is set up on dissolving the mineral in hot HCl.

Phenocrysts of olivine, augite, apatite, and felspar were set in a fine groundmass. Of these apatite is the only survivor.

The seven dykes appear to be of the same age, and of the same material, though apatite was found only in D_3. All have the same brownish yellow appearance, the same greasy feeling, the same degree of decomposition, and the same rich iron content, as shown by the iron oxide on the footwalls.

Age of the Dykes.—From their field appearance the basic dykes are all of the same age. The fact that the dykes (D_1 and D_2) are not intrusive into the overlying stratified Kainozoic grits, shows that they are older than either the Newer Basalt or the Kainozoic grits. The fact that they are intrusive into the Silurian sediments, and were not affected by the folding agencies of Lr. Devo-

nian times (16), stamps them as post Lr. Devonian. In one dyke (D_3) a few nodules of partly decomposed rock were found, and this tells us that the dykes are not very ancient. It is, therefore, reasonable to place them with the older basalt, because rocks of this age also occasionally show undecomposed nodules, and it was at this period that vast quantities of basic magma were forced to the surface.

Kainozoic Sediments.

These will be briefly described under the following heads:—

(a) Pre-older-basaltic river conglomerates.
(b) Pre-newer-basaltic grits (Normal "Tertiary Grits.").
(c) Eucalptus leaf beds.
(d) Pre-newer-basaltic river sediments.
(e) Inter-newer-basaltic grits, conglomerates, etc.
(f) Post-newer-basaltic grits, conglomerates and alluvium.

(a) *Pre-older-basaltic river conglomerate.*—This is found in the extreme S.E. of the area, and has been described above. No fossils were found. Part of this deposit has been altered to quartzite, evidently by the older basalt.

(b) *Pre-newer-basaltic grits and sands.*—These are generally stratified. Near Keilor, about two miles to the south, the grits are stratified, and marine fossils are abundant, but no fossils have been found in the grits of this locality, with the exception of the leaf beds described in the following paragraph. A close study leaves little doubt that all these sandy deposits have been derived from the Bulla granodiorite, the stratified and unstratified deposits apparently merging into one another.

(c) *Eucalyptus Leaf Beds.*—On the left bank of Deep Creek (See Plate XXXII.) a deposit of fine sands and very fine clay bands rests above sands, which in turn rest on the upturned edges of the Silurian sediments. These clay bands are overlain by other sandy layers. The whole deposit is about 30 ft. in thickness, and is covered by more than 100 feet of basalt. The clay bands consist of two sheets about 8 ft. in thickness, light blue resting on dark brown. Both are fossiliferous, but the brown are especially rich. The fossils are leaves of eucalypts, acacias, ferns, and other plants, together with stems and fruits of unrecognised plants. The eucalyptus leaves have been described by Mr. R. Patton (17). From the delicately even strata and the fineness of the clay, the deposit is evidently a lake deposit. The old surface of the Silurian rocks rises to greater heights on all visible sides of the leaf beds, and this, together with the lithological character of the sediments, is strong evidence in

favour of their lacustrine origin. There is no evidence as to whether these sands are pre-older-basaltic or post-older-basaltic. The examination of the eucalypt leaves by Mr. R. Patton threw no light on the problem of their age. From their position among the other sandy layers, with which they are conformable, it is probable that they are post-older-basaltic, like the normal Kainozoic grits.

The beds have a decided tilt to the S.E. This may be due to the compression of the loose porous sands by the great overload of new basalt, which here is about 140 ft. in thickness.

(d) *Pre-newer basaltic river sediments.*—These are shown on the map (Plate XXXII.), as areas where plant stems are very abundant. That they are river deposits is shown by their lenticular shape, by the small conglomerate that rests on the valley floor, and by the earthy nature of the matrix. They indicate the sites of pre-newer basaltic valleys.

(e) *Inter-newer basaltic grits and conglomerates.*—The lava flows of the newer basalt in this district are divided into two series—Upper and Lower. This will be explained later. Between the two series is the old soil surface of weathered rock, and in places thick deposits of grit have gravitated from the higher granodiorite in the locality into the valleys corroded in the Lower Series of the newer basalt. These grits, etc., are not stratified. They act as a simple division between the two series of newer basalt. The best occurrences are at points marked F on the map. At Column Gully a heavy conglomerate of quartz and basalt pebbles separates the two series, while in the road cutting north of Bulla an old land surface separates them.

(f) *Post-newer basaltic grits, conglomerate and alluvium.*—All these should be placed as Recent, but as they form only a later stage in the same destructive and constructive process that has been going on right through the Kainozoic, they have been placed under this head. In the neighbourhood of the heart-shaped granodiorite outcrop, unstratified grits can be seen both above and below the newer basalt. The grits have been shed from the hill. This process went on before the older basalt, before the newer basalt, and it is being continued after it. Grit covers or mixes with the basalt soil.

In addition to the massive conglomerates that are now being formed in the stream beds, there are conglomerates of much earlier age formed along the river spurs, especially those of Jackson's Creek, where the deposits are sometimes at least 30 feet in thickness. Generally, they are chiefly rounded quartz and basalt pebbles, and can thus be distinguished from the normal Kainozoic pebble

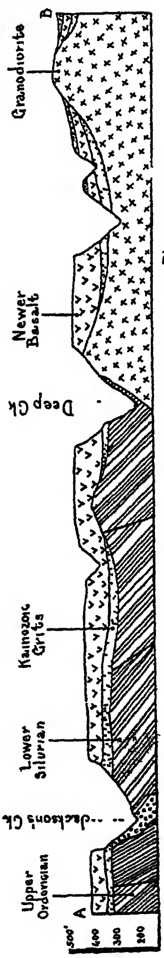
beds which contain no basalt. These deposits have been dropped by the stream as it deepened its bed, but yet the fact should be noted that the great mass of this conglomerate occurs about 100 feet above the present stream level, i.e., when the stream had sunk its bed a little more than 100 feet below the surface. This shows that at that depth the stream cut into an old Kainozoic pebble deposit to the north, and distributed the pebbles on the convex bank of its meanders. The pebbles lower than 100 feet have probably been derived partly from the old pebble beds, and partly from the recent deposits higher up the spurs.

River alluvium, as already described under Physiography, is poorly represented in this area. It is found chiefly on the down-valley side of the spurs, and it usually passes into and overlies a heavy river conglomerate. The best deposit is found on Jackson's Creek, near its junction with Deep Creek.

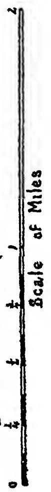
Newer Basalt.

Newer basalt covers more than nine-tenths of the area mapped. It appears to consist of about seven flows that have come from Red Hill, Sunbury Hill and Bald Hill. This is shown by the contour lines on the military map, by the dominating position of these volcanoes, and by the shape and direction of the vesicles in the basalt. The points of origin of the earlier flows have not been determined. In many places the basalt has a depth of over 300 ft., but it cannot be said from this that each flow is 43 ft. in thickness, for the earlier flows are by far the deepest, since they levelled the old denuded surface. In the neighbourhood of Column Gully excellent columnar structure has been produced in the earlier flows. A description of these columns (14) and the factors producing them (18) may be found in other publications.

Upper and Lower Series.—The various flows of newer basalt in this area are divided into Upper and Lower Series by sandstone bands, river conglomerates, or thick surface soil. The places where a good junction of the Upper and Lower Series can be seen is marked F on the map. That a considerable time interval elapsed between the two series is shown by the denuded surface of the Lower, by its older appearance and more decomposed state, and by the thickness of surface soil on the Lower Series. Generally the thick scree on the valley sides masks the division line of the two series, but excellent junctions are common, especially in the N.W. of the area.



Geological Section along AB on the Map Shown on Plate XXXII.



It might be thought that the Lower Series belongs to the Older Basalt, but there is strong evidence against this:—

(1) The Lower Series rests in places on thick deposits of sand, which appear to be the normal Kainozoic grits.

(2) The river conglomerates between the two series frequently contain basalt pebbles derived from the lower series. These pebbles are only slightly decomposed. If they were older basaltic they would be thoroughly decomposed.

(3) Older basalt, three miles to the E.S.E., is thoroughly decomposed, while the lower series described above is only slightly weathered.

Scoria Cone.—Near the junction of Column Gully and Jackson's Creek is a scoria cone which was almost submerged by the youngest lava flows. A study of the sections shows that at first effusive and explosive eruptions alternated, and then gave place to a prolonged discharge of scoria and agglomerate. The uppermost of the four layers of scoria is still about 100 feet thick. Probably denudation has reduced its thickness. At one point a wall of dense basalt pierces the scoria. It is evidently a blocked up vent, or dyke.

The scoria is of the same age as the "Organ Pipes," and the columns in Column Gully, and, therefore, belongs to the Lower Series of Newer Basalt. At one point on Jackson's Creek scoria overlies and underlies the columnar basalt.

Microscopic Examination of Upper Newer Basalt.—Sections were made of very tough basalt from the small quarry on Deep Creek, north of the Leaf Beds. It proved to be a hypocrystalline rock, in which some glass was present. Large phenocrysts of olivine were set in matrix of fairly coarse labradorite. Augite and magnetite were very abundant, while iddingsite frequently replaced the olivine. The sections gave good examples of ophitic structure, for augite commonly included the labradorite laths. Flow structure was illustrated by the orientation of the labradorites, and the manner in which they "flowed" round the olivines. The rock was a coarse grained basalt.

Porphyritic Basalt.—In the triangle between Redstone Hill, Bulla and the Organ Pipes, there is a peculiar flow of dense porphyritic basalt that belongs to the Upper Series. Near the Redstone Hill, a volcano on Jackson's Creek, it is found resting directly on the sands that separate it from the Lower Series. In several places in Deep Creek and Jackson's Creek it is found in a perfectly fresh state, but above the Organ Pipes it appears in a more weathered and vesicular state. Boulders of this porphyritic basalt

in the stream can readily be identified by the smooth light-brown surface spotted with black augite crystals. Under the microscope sections show that the rock contains perfectly fresh plagioclase, augite, and olivine phenocrysts up to ½ in. in diameter, set in a finer paste. The rock closely resembles the Tweed Head basalt of Queensland.

Acknowledgments.

The writer is deeply indebted to Prof. E. Skeats for the interest and encouragement always given, and for the help, advice and suggestions which have acted as a guide to the matter in this paper.

Thanks are also due to Mr. F. Watson for the chemical analysis of the Bulla granodiorite.

The writer desires to acknowledge his great indebtedness to Dr. H. S. Summers for his valuable criticism of the method of presentation and of the matter given here.

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DESCRIPTION OF PLATES.

Plate XXXII.

Geological map of the Bulla-Sydenham Area.

Plate XXXIII.

Fig. 1.—Type of kaolin deposit due to pneumatolysis.

Fig. 2.—Type of kaolin deposit formed by the action of atmospheric water and gases.

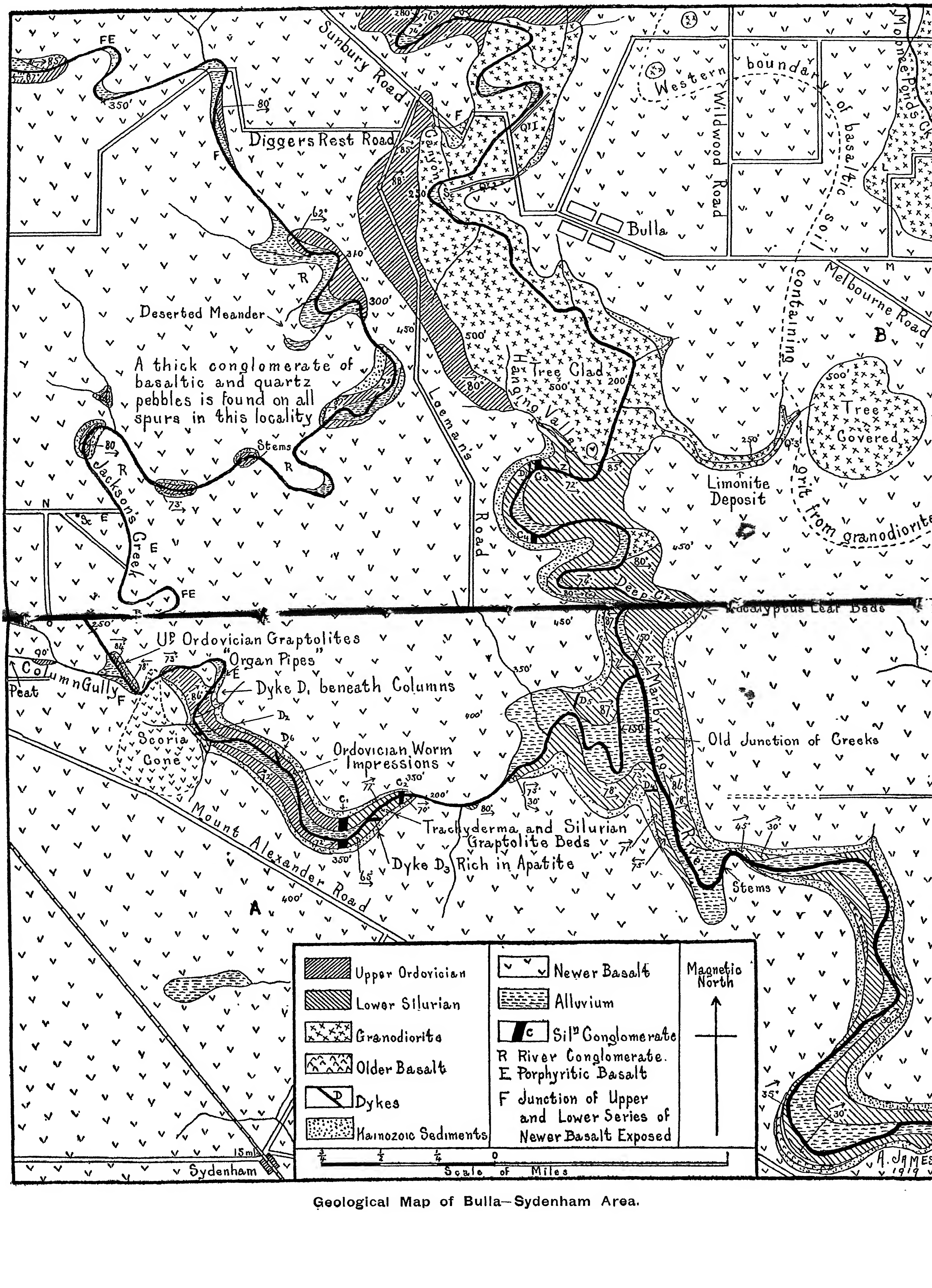
Fig. 3.—Meanders of Deep Creek. The heavy line shows the present course of the stream; the dotted line indicates the original course of Deep Creek.

Fig. 4.—Primary and secondary meanders of Jackson's Creek. The heavy line shows the present course of Jackson's Creek, with both primary and secondary meanders, while the dotted line indicates part of the original course of the stream on the surface of the basalt (with primary meanders). The large curves are primary, and are produced by the inequalities in the original land surface, but the small meanders are secondary, and are due to subsequent stream development.

Fig. 5.—This diagram shows how the bed of a stream in the spurred type of entrenched meander moves both horizontally and vertically.

Plate XXXIV.

Fig. 1.—Photograph of a spurred entrenched meander on Deep Creek. Water-worn pebbles are found along the crest of the spur. The flood plain on the down-valley side of the spur has been caused by the down-valley sweep of the meander. At the point x are the Eucalyptus Leaf Beds.



Geological Map of Bulla—Sydenham Area.

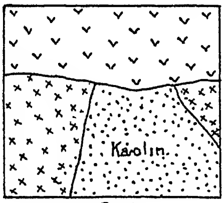


Fig. 1

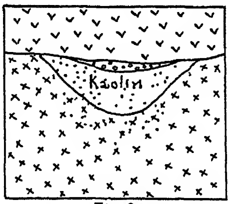


Fig. 2

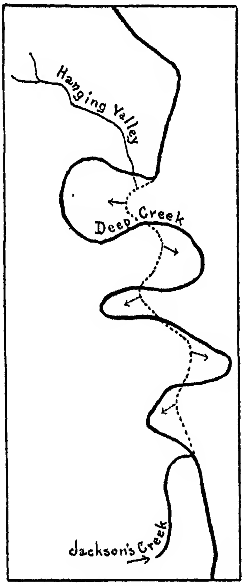


Fig. 3

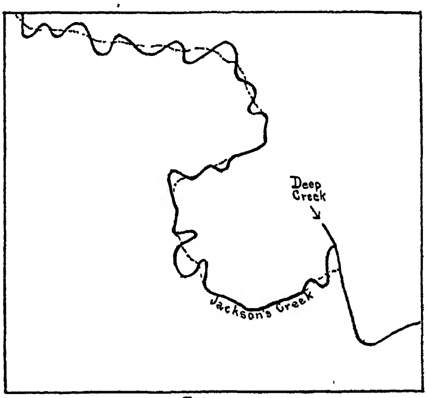


Fig 4

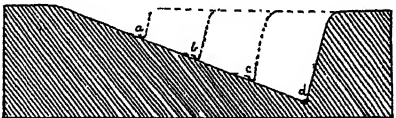
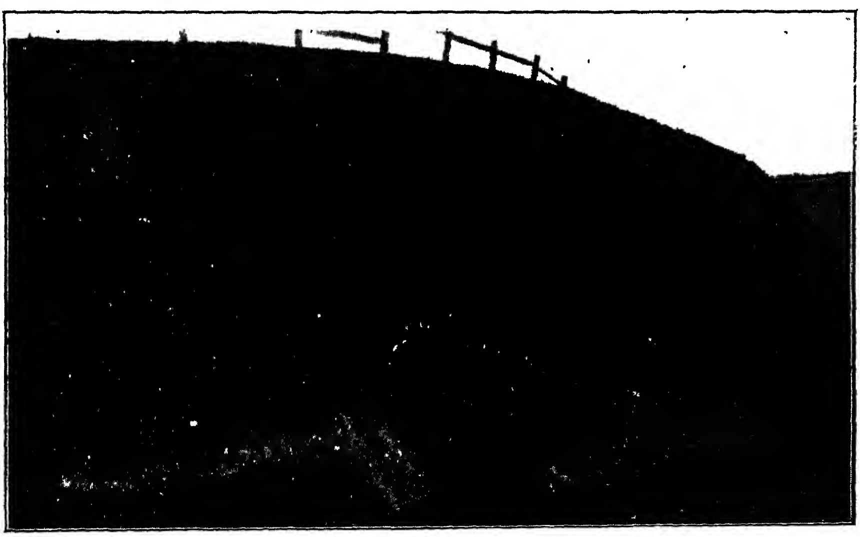


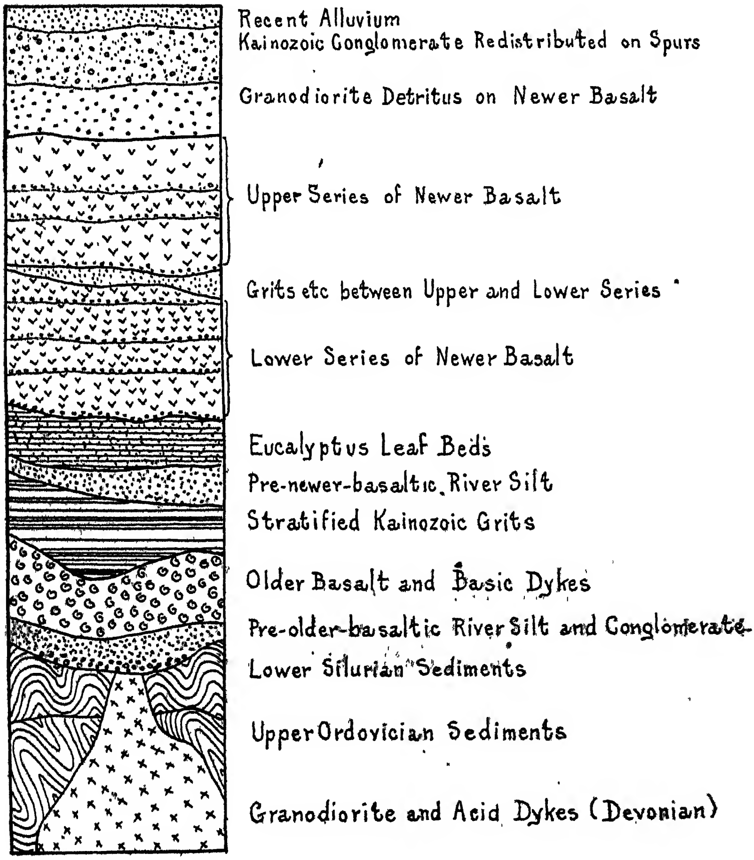
Fig. 5

Kaolin deposits and river meanders



Spurred Meander and Junction of Upper and Lower Basalt

Fig. 2.—Photograph of the junction of the Upper and Lower Series of Newer Basalt, near the Canyon, Bulla. The Lower Series is resting on grits, which show slight step-faulting. The Upper Series is seen resting on the weathered surface of the Lower Series. The junction of the two basalts is indicated by xx on the photograph.



Rocks of the Bulla-Sydenham Area Arranged in Chronological Column.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. I., 1919].

ART. XXII.—*On the Seasoning of Hardwoods.*

BY R. T. PATTON, B.Sc.

[Read 11th September, 1919].

The results given in this paper do not claim to settle, in any way, the question of seasoning, but are rather a record of accurate observations made on our timber when treated in various ways. In the discussions on seasoning, opinion is more often quoted than observation.

Steaming of timber, prior to seasoning, has many advocates, and this process has been given a good deal of attention. In the Botanical Laboratory, we have only been able to use 2 ft. lengths, but I do not think that this has any marked effect on the result. It may, however, since the wood vessels in the tall eucalypts are very long, and hence the steam may find its way right into the wood. If the wood be saturated with moisture, when it is put into the steam bath, it is difficult to see how the wood could dry, since the air is also saturated. On the other hand, if the wood be partly seasoned, then it ought to take up moisture. The latter case was not investigated. In the former case, however, all specimens weighed approximately the same when taken out as when put in. Steaming may, as Tiemann points out, prove a ready means of heating the wood, but the same result could probably be secured in another way. In the former experiments, the results of which are published in the Proc. Roy. Soc. Victoria, Mountain Ash (Eucalyptus regnans) was mainly used, but in this series Messmate (E. obliqua) was mainly used. The general results are the same. In the first place there is no acceleration of drying after steaming. Typical examples are given below. The weights are given as percentages of original weight. The boards were 6 in. x 1 in. Messmate, and were all cut from the same length of timber.

Date	Treatment. In air	24 hrs. in steam	Air	48 hrs. in steam
	%	%	%	%
4/11/18	100	100	100	100
9/11/18	91.5	87.5	90.9	89.3
19/11/18	82.8	82.7	83.8	80.8
29/11/18	77.4	75.8	76.7	75.5
16/12/18	68.8	69.0	69.7	68.1
8/1/19	65.6	65.5	66.7	63.8
28/1/19	64.5	64.4	65.6	62.8
14/2/19	64.5	64.4	64.7	63.8

It will be seen that the specimen steamed for 48 hours has lost slightly more than the others. This is often the case, as tannin and kino are dissolved out of the wood.

While the drying rate is not affected, the amount of shrinkage is seriously affected. Two typical cases are given. The timber was 6 in. x 1 in. messmate. The first specimen was steamed for six hours, and then put out in the air to dry. The corresponding piece was left in the air.

		Steamed	Unsteamed
Shrinkage	Breadth	$\frac{18}{32}$ in.	$\frac{11}{32}$ in.
	Depth	$\frac{3}{32}$ in.	$\frac{2}{32}$ in.

The second specimen was steamed for 12 hours.

		Steamed	Unsteamed
Shrinkage	Breadth	$\frac{17}{32}$ in.	$\frac{11}{32}$ in.
	Depth	$\frac{4}{32}$ in.	$\frac{3}{32}$ in.

It will be seen that the steaming has greatly increased the amount of shrinkage. The cause of this extra shrinkage is not yet known, but it may be due either to the steam affecting the union of the cells or the constitution of the cell wall may be affected.

A very interesting result was obtained by cutting a length of 6 in. x 1 in. timber into 10 in. lengths, and subjecting each piece to a different mode of treatment before putting it out in the air to dry.

The result of one experiment is as follows:—

Date	Treatment: In air	Treatment: 2 hrs. in steam at 10 lbs. pres.	Treatment: 2 hrs. in steam at atmos. p.	Treatment: In oven at 110°c
	%	%	%	
7/11/18	100	100	100	100
9/11/18	97.4	95.4	96.8	93.1
19/11/18	89.9	88.5	89.2	88.6
29/11/18	86	83	84.3	84.7
16/12/18	80.8	78.3	79.5	79.7
8/1/19	78.6	76	77.6	77.4
28/1/19	77.8	75.2	77.9	76.6
14/219	77.7	74.9	76.9	76.4

The weights are given as percentages of the original weights. It will be noticed that the piece treated at 10 lbs. pressure of steam is the lightest. This is due to various substances being dissolved out of the wood. The interesting feature of the experiment lies in the fact that all the pieces have dried approximately at the same rate. With the exception of the second weighing, the difference between any pair of weights never exceeds 3% at any weighing, and in this 3% difference must be included the loss of

tannin and kino. The difference between the un-treated specimen and the oven-treated specimen is very small. Other experiments gave the same results. Hence we may conclude that sudden drying of the surface does not affect the ultimate rate of drying.

The amount of shrinkage in breadth of these specimens is also of interest:—

	Treatment			
	In Air	10 lbs. steam	Steam at atmos. p.	Oven at 110
Shrinkage	$\frac{17}{32}$	$\frac{18}{32}$	$\frac{17}{32}$	$\frac{16}{32}$

These results are similar to those of other experiments. It will be seen that the suddenly dried specimen gives the least shrinkage.

The amount of shrinkage that takes place when our timber is seasoning, is highly important. The measurements taken are not extensive, but they should prove a guide for future work.

Measurements were made on both Messmate and Mountain Ash. In length the shrinkage is very small, and averaged 1/32 in. for 6 ft. Lengths from 2 ft. to 6 ft. were used.

For shrinkage in radial and tangential direction, 6 in. x 1 in. boards were used mainly. The shrinkage in a tangential direction is generally supposed to be much greater than in a radial direction, but the difference was not as great as expected. The results for Mountain Ash (E. regnans) are as follows:—

In the radial direction the shrinkage averaged—

$\frac{10}{32}$in. for 6in. or about 5%.

In the tangential direction the shrinkage averaged—

$\frac{1}{2}$in. for 6in. or about 8%.

For Messmate the results were as follows:—

In the radial direction the shrinkage averaged—

$\frac{12}{32}$in for 6in. or about 6%.

In the tangential direction the average was—

$\frac{15}{32}$ for 6in. or about 8%.

It is still a debated question as to how long it takes our timber to season in the open air. Apparently no accurate observations have been made, and hence doubt exists. In my former paper I gave some observations on the drying of a stack of timber. Another stack was made in January of this year. The boards were 6 in. x 1 in., and were placed horizontally with 1 in. fillets between them. Laterally there was a 3 in. space between boards. There were 30 boards in the stack, each 6 ft. The stack was not in the

most favourable position for drying, since it was shut in by walls on three sides, and was beneath an elm tree. The lowest humidity recorded was 13%, and this was on the day of the disastrous fires in the Otway Ranges. All the boards dried in about four weeks. The percentage of moisture remaining was about 12 %, this being the average of three boards.

The actual and percentage weights of the boards that lost most are as follow :—

Date	Weight	%	Weight	%
18/1/19	16.6	100	16	100
25/1/19	13.3	80.6	12.5	76.9
1/2/19	11.14	72.5	10.15	68.4
8/2/19	10.15	66.8	10.1	62.9
15/2/19	10.6	63.4	9.12	60.9
22/2/19	10.5	63.0	9.14	61.7
1/3/19	10.4	62.6	9.14	61.7

It will be noticed that the latter one began to weigh more. This is always the case with dry boards, for they vary with the humidity of the atmosphere. The result of this experiment indicates the need for more extensive observations on the natural drying of timber in our climate, especially during the summer. If inch boards can be seasoned by a month's air drying in summer time, to kiln-dry such boards would be quite unnecessary and would hardly save any time. I desire to thank the manager of the Victorian Hardwood and Milling Co., and also Messrs. R. Grundy and Co., for their care and promptness in supplying the timber for these experiments.

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The names of new genera and species are printed in italics.

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END OF VOLUME XXXII., PART II.

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